AUDIO ENGINEERING

OCTOBER
1951
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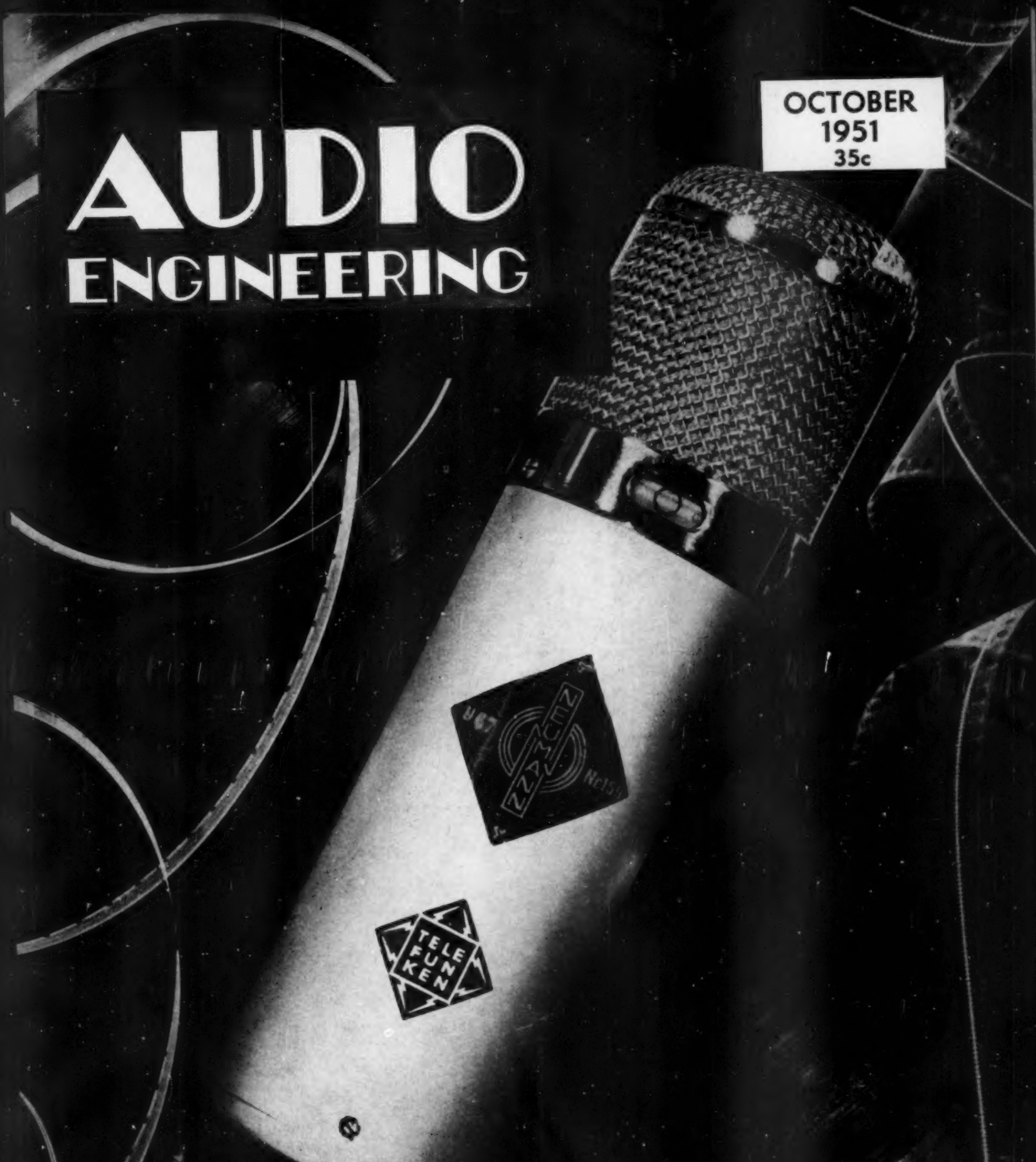

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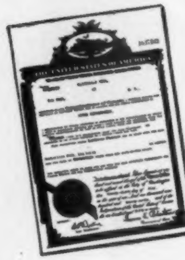

AUDIO PATENTS

RICHARD H. DORF*

DIRECT-COUPLED AMPLIFIERS are more or less passé these days in audio work, probably largely because they were so difficult to adjust and keep in adjustment, what with the complex power-supply bleeder systems commonly used and the high B-voltage necessary. There is still, however, a distinct need for d.c. amplifiers in many instrumentation applications and some audio men are still enamoured (and justly so) with the bass response they make possible.

One way to avoid the complicated bleeder is to supply B-plus to each stage, in the usual R-C-amplifier manner, through a load resistor and ground the cathode, but place a battery between the plate of one stage and the grid of the next to cancel the positive voltage transfer. This requires a number of batteries or independent voltage sources and is too cumbersome. Raymond A. Minzer of Watertown, Mass., has come up with a system which uses this basic philosophy but uses only one, or at the most, two power supplies for the entire amplifier. His simple

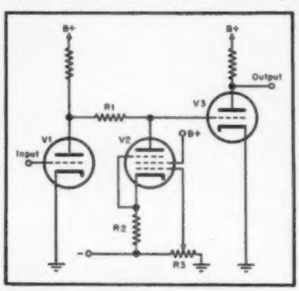

Fig. 1.

circuit, the subject of Patent No. 2,554,469, is diagrammed in *Fig.* 1.

V_1, the first amplifier stage, is conventional, using any convenient bias method (not shown) and having a plate-load resistor connected to B-plus. V_3, the second stage, is also conventional. R_1 is placed in series between the two stages.

V_2 is a pentode, called the "d.c. level changer." Its cathode is connected to a source of negative power, which may either be separate from the main B-supply or may be obtained by a standard bleeder system. Current in V_2 passes from the negative supply through the tube, R_1, the load resistor of V_1, and back to ground through the B-plus supply. In passing through R_1, which may have a high value, it creates a d.c. voltage drop which makes the grid end of R_1 negative with respect to the plate end. The value of R_1 and the positive grid bias for V_2 (adjusted with R_3) are made large enough so that the net potential at the plate of V_2—and therefore the grid of V_3—is actually somewhat negative with respect to ground, thus giving V_3 the correct operating bias.

All this, however, does not cause any appreciable audio voltage loss, for the combination of R_1-V_2 does *not* act as an audio voltage divider. The reason is that V_2, being a pentode with constant screen and control-grid potentials, is essentially a constant-current device. The audio-voltage variations at its plate do not produce appreciable variations of current. Thus the current through R_1 remains unvaried and there is no a.f. voltage drop across it. Both because R_1 may have a rather high value and because the plate resistance of a pentode is high, the arrangement does not appreciably shunt V_1 to reduce its gain. The result is direct coupling with all its advantage, with, at the same time, conventional operation of the amplifier stages.

As many stages as necessary can be handled in exactly this same way, a level-changer tube being inserted between each pair, all operated from the same negative supply. In operation, the only adjustment is setting R_3 for the correct bias on V_3. A triode may also be used for V_2, with a value for R_2 of 0.5 to 1.0 meg. With the pentode, R_2 is present to introduce some degeneration to make the circuit more stable; the high value used with a triode, normally a constant-voltage source, makes it the equivalent of the constant-current pentode.

Calibrating Sound-Level Meters

Building and using sound-level meters is among the more frustrating aspects of the

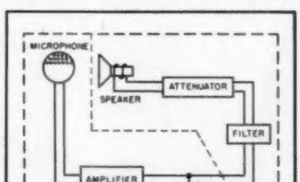

Fig. 2.

audio art, largely because calibration of the instrument as a whole is so difficult. Microphones (especially the crystals ordinarily used) and amplifiers vary in sensitivity and gain with weather and age, and unfortu-

[*Continued on page 4*]

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COVER

The Telefunken Type U47 condenser microphone, although introduced in this country only recently, is receiving marked acceptance among major recording studios and broadcast stations. This interesting study was photographed at Reeves Sound Studios, New York.

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nately there is almost no reliable way of recalibrating except with a standard sound source in a completely dead room. This is done at the factory but is usually impossible for the user.

Augustus H. Fiske, Jr., assignor of Patent No. 2,558,550 to General Electric, has attacked the field recalibration problem in a neat and simple way, as *Figs.* 2 and 3 illustrate. A measure of the sensitivity and gain of an entire system involving amplification is the threshold of oscillation. As *Fig.* 2 shows in block manner, an ordinary sound-level meter consists of a microphone, amplifier, and level indicator. When the microphone has a certain sensitivity and the amplifier a certain gain, the meter is calibrated to indicate sound levels in decibels (or phons in elaborate instruments). Mr. Fiske adds a calibration circuit consisting of a dynamic speaker connected through an attenuator and possibly a filter to the amplifier output, in parallel with the meter.

With the microphone and speaker tightly coupled acoustically, the system will begin to oscillate when the combined sensitivity of the microphone and amplifier is at a certain point. If a gain control is provided in the amplifier, and if it is set during each calibration so that the system just begins to oscillate, the total sensitivity of microphone and amplifier to measured sounds will always be the same, assuming (with justice) that the efficiency of the speaker and the loss in the attenuator do not change appreciably. The filter, tuned to a single frequency, may be inserted for greater calibration accuracy.

In use, then, the microphone, amplifier, and meter are initially calibrated at the factory against a standard sound source in the usual way. Then the microphone and speaker are coupled and the attenuator is adjusted so that the system just breaks into oscillation. In the field, the system can be recalibrated whenever the operator wishes, simply by coupling microphone and speaker and adjusting the amplifier's gain control so that oscillation begins. This is a calibration of the whole meter, since any change in microphone sensitivity—or of amplifier gain —will be offset by the adjustment of amplifier gain. The speaker and attenuator can be expected to keep their initial characteristics for a good long time, so remain reliable.

Figure 3 shows how the microphone and

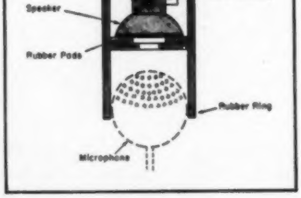

Fig. 3.

speaker can be coupled acoustically for full sound transfer, uniform from one time to the next, and eliminating any effects of surrounding acoustics. A metal housing with a shelf holds the speaker upside down, with the rim of the speaker lying on rubber pads and being held by the spring. The microphone is inserted in the bottom of the

[*Continued on page 51*]

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AUDOGRAPH

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LETTERS

Record Lists

Sir:

I would like to express my appreciation for the abbreviated evaluation of new records which now appears in Mr. Canby's column. By all means continue and expand this work. When audio is a serious hobby, the demand for good records also becomes serious, for a good system is of little value without good records as source material.

At some time in the future, may we have a listing of suitable recordings for "background music"? There are many of us whose devotion to symphonic music does not include 100 per cent of our listening time, and it is difficult to select this type of music simply from titles in catalogues. In order to obtain even a dozen such records, I have already procured over fifty and I am still unsatisfied. I would like a library of records of the type used by the wired music services—those with no great crescendoes or changes of tempo which would distract a person's attention from other occupations.

Neil MacCoull,
Fishkill, New York

Intelligent Correction

Sir:

Permit me to call your attention to a mistake in Jerome Goodman's article "Music and Mass Production" (Æ, Sept. '51). In this article, the author gives the impression that I.Q. is measured in per cent. The letters *I. Q.* are an abbreviation for *intelligence quotient*, or the ratio between mental age and chronological age. This ratio, multiplied by 100, gives the I.Q., which we in the social sciences usually term an index of brightness. Perhaps this is a minor point, but I think it important that technical terms, whether native to one's field or not, be used correctly. The probable unfamiliarity of most readers with this technical definition of I.Q. makes it all the more important that any discussion of it be correct to preclude any further misconception about the notion.

D. E. Clark

(*Thus isn't mental age a percentage of chronological age?* Ed.)

Credit to Co-Author

Sir:

Many thanks for your presentation of the article on the Space Charge Amplifier (Æ, Sept. '51). While I am grateful for the "plug" in the sub-heading, but I feel it is only fair to call attention to the true status of the work on the original Musician's Amplifier. The bulk of the layout and arrangement work was done by David Sarser, while I contributed suggestions and ideas to eliminate some of the troubles encountered in adapting it to American parts. Therefore, I feel that Mr. Sarser is entitled to equal recognition or possibly even sole recognition for his work in making the amplifier the success that it has become. Dave and I have always worked together as a team and it is not my intention that he be slighted in any way.

Melvin C. Sprinkle,
Altec Lansing Corp.,
161 Sixth Ave.,
New York 13, N. Y.

(*That's one on us—we wrote the subhead.* Ed.)

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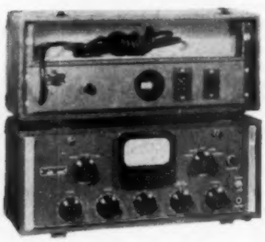

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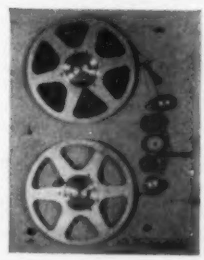

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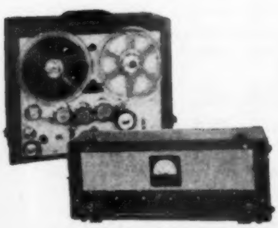

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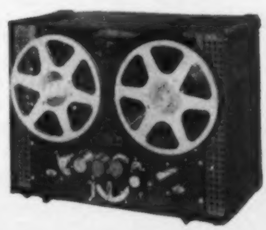

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EDITOR'S REPORT

THE PACIFIC ELECTRONIC EXHIBIT

HELD IN CONJUNCTION with the 1951 Western Convention of the Institute of Radio Engineers, the 7th Annual Pacific Electronic Exhibit has come and gone—and a bang-up exhibit it was. Excellently attended, and in a convention hall admirably suited to such an affair, it was somewhat of a surprise to those of us who have succumbed to the average New Yorker's provincialism. The many booths were crowded from opening to closing for the three days of the show, and it was necessary to darken the hall to get the visitors to go home on the final evening. And with nearly sixty papers on a wide variety of subjects—presented in thirteen sections in eight periods so that no one could possibly attend all of the papers—the convention itself was a huge success.

We consider ourselves fortunate to have been able to attend this convention and exhibit for a number of reasons—we were able to meet and discuss audio with many old friends, we saw and heard a number of new developments, and we learned that the Pacific Coast is well on its way toward besting the East in electronic developments.

THE AUDIO FAIR

While the AES Convention is held at the same time as the Audio Fair, it is the Fair which attracts the greatest attention and attendance. For the benefit of those who are not professionally engaged in the Audio profession, the convention papers which are of greatest interest to this group—the hobbyists—are scheduled for the session on Saturday morning, November 3, beginning at 10:00 a.m. Friday morning's session will be devoted to industrial aspects of audio, and the afternoon session on the second day will cover recording. The opening day's sessions will be devoted to components, instrumentation, and related subjects.

Two floors of Hotel New Yorker—the fifth and sixth—will be filled with exhibitors with all types of devices of interest to anyone whose vocation or avocation involves audio. Several new speakers are due to be unveiled—both woofers and tweeters; new amplifiers will make their debut; magnetic recorders, both professional and non-professional will be watched with interest. Above all, the Audio Fair will permit these developments to be *heard,* as well as seen. It is this one feature which has made the Fair of nation-wide interest in so short a time. Audio as a separate industry and a separate profession has certainly become recognized.

This year, for the first time, wives of audio people are being recognized. Announcements of the convention being sent to members list a number of activities available for those wives who may wish to accompany their husbands to New York for the gala affair. This addition will probably bring out some who would not otherwise come—and *vice versa.*

INTERNATIONAL STANDARDIZATION

The Sixth Plenary Assembly of the International Radio Consultative Committee (C.C.I.R.) met in Geneva, Switzerland during the month of June and made considerable progress toward standardizing recording characteristics for radio programs destined for international exchange. Departing from the AES recommendation that no disc recording characteristic be standardized—only that for a standard playback system—the committee presented for further study a number of existing recording characteristics with the recommendation that such compromises be made by the various countries represented as would permit complete agreement upon one standard curve.

The proposed compromise characteristic provides for a 450-microsecond curve below 1000 cps and a 50-microsecond curve above 1000 cps. This corresponds to a low-frequency turnover of approximately 360 cps and a high-frequency turnover of approximately 2800 cps, as compared to the AES Playback Characteristic of 400 and 2500 cps respectively. While our preference still remains for the AES curve—both as to frequency of turnover and as to its specification as a *playback* characteristic instead of a recording standard—it appears that the proposed curve would fall within the tolerance allowed by the AES curve and would thus provide satisfactory reproduction when played on equipment engineered to AES standards. The Society's recommendations have already been forwarded to Neal McNaughten, the member of the Preparatory Group from the U. S., and it is to be hoped that his influence may help to swing the other members more closely to our already-adopted standard.

The C.C.I.R. standardization is not intended to apply to any recording intended purely for use in the individual countries, but only to those programs which are intended for international distribution or exchange. However, it is felt that if the equipment is made to satisfy the standards for programs in the exchange category, it is probable that it would be used without change for the locally consumed recordings, with consequent benefit to all who use them for any purpose whatsoever.

ELECTRONICS OFFICERS, AIR

Recent communications from the Public Information Office of First Air Force Headquarters indicate that men with a university degree and suitable qualifying experience in electrical, communication, radio, or electronics engineering may possibly step directly from civil into military life with a commission in the Air Force Reserve.

Depending upon age, commissions from second lieutenant to major may be granted those who qualify. A master's degree in one of the specified fields, or a bachelor's degree followed by at least a year of experience are prerequisite.

Equivalent Circuits to Simplify Feedback Design

RICHARD S. BURWEN*

Treating a feedback amplifier in terms of its equivalent non-feedback type makes it easier to determine its performance characteristics.

CALCULATIONS may be simplified through the use of equivalent circuits in the application of selective feedback to amplifier design, as will be shown in this article.

A selective feedback amplifier circuit is often best (and most economical) when designing an equalizing network or tone control system to produce a given frequency response. Though feedback calculations are usually more difficult than those required for conventional circuits—because it is necessary to vary the amount and phase of feedback with frequency in a manner that will result in the specified amplification curve—the work is usually worth while. It often results in lower distortion than when using interstage equalization, as well as in lower output impedance, more efficient utilization of the available gain, and less expensive components.

With the simple interstage resistance-capacitance networks commonly used in phonograph preamplifier and tone-control circuits, an experienced designer can determine easily what the frequency response will be; he can approximate the curve with straight lines having 0 or 6 db per octave slopes and pick out the frequencies where the slope changes. It is apparent that when a feedback amplifier is reduced to a generator feeding such an interstage network, the task of fitting a given response curve or of calculating the response curve of a given amplifier will be greatly simplified.

* *17 Sheffield Road, Melrose 76, Mass.*

General Feedback Amplifier Equivalent Circuit

The general feedback equivalent circuit is shown in *Fig.* 1. This equivalent circuit is applicable to any amplifier involving voltage and current feedback, both positive and negative.

The circuit is derived from the two equations shown for the gain and internal impedance of a feedback amplifier. By shutting off the generator one can see that the internal impedance, that of the two branches in parallel, checks with the formula for Z_o'. Disconnecting Z_L leaves a simple voltage divider that taps off a fraction

$$\frac{\dfrac{1}{-A_o\beta}}{1+\dfrac{1}{-A_o\beta}}=\frac{1}{1-A_o\beta}$$

of the amplified input signal A_oE_{in} in agreement with the formula for E_o when $Z_L=\infty$.

Whether or not the network is actually simple depends upon how complicated the four impedances are and whether or not the gain without feedback A_o is the same at all frequencies. In practice each of the impedances may be a network of several elements; while in a few very useful cases all but one or two may be pure resistances. (The use of these equivalent circuits assumes linear operation of all the tubes and elements).

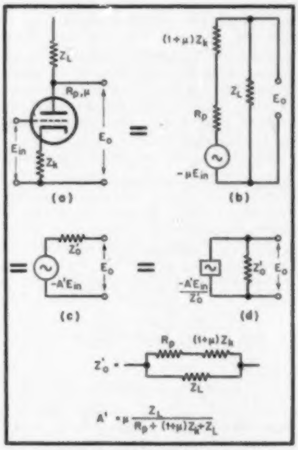


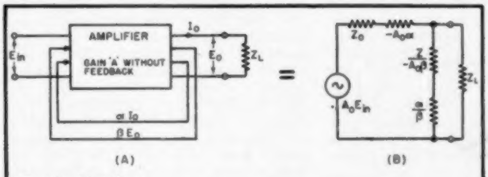
Fig. 2. Equivalent circuits for cathode current feedback.

Equivalent Circuits For Cathode Current Feedback

One of the most useful applications of this equivalent circuit is to a single amplifier stage with cathode current degeneration, shown in *Fig.* 2. This type of stage is useful as a treble-boost circuit simply by shunting the proper capacitance across the cathode resistor. In event that Z_L consists effectively of the plate resistor and the following-stage grid resistor in parallel, and Z_K is a pure resistance it is convenient to reduce the entire circuit to a generator and a single resistance Z_o'.

Plate-to-Grid Feedback

The triode with plate-to-grid voltage feedback, shown in *Fig.* 3, is somewhat more complicated. In this circuit the feedback part is as simple as that of the triode with cathode current degeneration. But two more factors have to be taken into account. The first is that Z_g loads the input impedance Z_i causing a loss of voltage across Z_i even without



Z_L = Load Impedance
A = Gain of amplifier with no feedback and Z_L connected
A_o = " " " " " " " " disconnected
Z_o = Internal impedance seen looking into the output terminals with no feedback and Z_L disconnected.
Z_o' = Internal impedance seen looking into the output terminals with feedback and Z disconnected.
E_{in} = Input signal voltage
E_o = Output voltage across load
I_o = Current in the load
α = Current feedback factor = $\dfrac{\text{feedback voltage developed by current in load}}{\text{current in load}}$
β = Voltage feedback factor = fraction of the output voltage fed back
E_f = $\alpha I_o+\beta E_o$ = total feedback voltage due to voltage and current feedback and is considered as being directly added to E_{in}

$$E_o=\frac{AE_{in}}{1-A\left(\beta+\frac{\alpha}{Z_L}\right)}$$

$$Z_o'=\frac{Z_o-A_o\alpha}{1-A_o\beta}\qquad\text{when } Z_L=\infty,\ A=A_o$$

Fig. 1. General feedback amplifier equivalent circuit.

feedback. The second is a direct path from input to output through Z_1 and Z_2 by-passing the tube. (These effects may be observed by disconnecting the grid of the tube from the circuit and grounding it.) Almost every feedback amplifier has such a path. Usually it is neglected because the amount of signal at the output coming directly through the feedback network is very minute compared to the signal from the tubes.

To take these two factors into account, the equivalent non-feedback circuit has been drawn in two parts, as at (B). The signal is first attenuated in the left circuit by the factor $Z_2/(Z_1+Z_2)$, giving a new input voltage E_{in}'. Next the signal voltage E_{in}' is amplified and fed into an interstage equalizer derived from *Fig.* 1. The additional branch consisting of a series arrangement of Z_1, Z_2, and a generator E_{in} takes care of the direct path from input to output and the plate loading due to Z_1+Z_2.

Note that in (B) of *Fig.* 3 the voltage

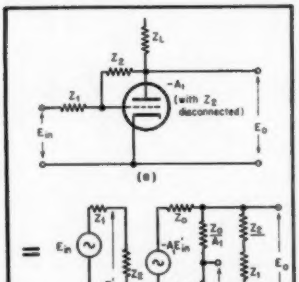


Fig. 3. Equivalent circuits for plate-to-grid feedback.

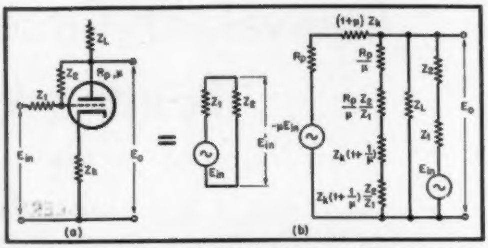


Fig. 4. Combined grid and cathode feedback equivalent circuit.

E_o' is just $E_oZ_2/(Z_1+Z_2)$. By taking E_o' as the output voltage, then, the left portion of (B) can be eliminated. (C) in *Fig.* 3 shows the resulting circuit. Another branch has been added for the purpose of correcting the output impedance Z_o' back to its proper value as seen at the output terminals in (B).

Frequently the internal impedance of the balance of the circuit is so small compared to Z_1+Z_2 that the loading effect of Z_1+Z_2 on the output and the amount of signal fed directly through are negligible. In this case the circuit can be reduced to a simple T network, as at (D). The impedance $Z_o/(A_1+1)$ is an approximation of the corresponding branch in (C). In calculations of open-circuit frequency response this branch can be completely disregarded. It serves only to indicate the minimum internal impedance when Z_2/Z_1 becomes very small.

The approximate equivalent circuit using a constant current generator is shown at (E).

Combined Grid and Cathode Feedback

The circuit equivalent to a triode with both plate-to-grid voltage feedback and cathode current feedback is shown in *Fig.* 4. On account of the complexity of this circuit, however, it is frequently easier to consider the two types of feedback separately.

This is the case when Z_L and Z_K are pure resistances. The procedure is to consider first the triode with cathode current degeneration as (A) in *Fig.* 2. The circuit is then reduced to a generator $-A'E_{in}$ with an internal impedance Z_o' as at (C) in *Fig.* 2, which can now be redrawn in the form of the original circuit, (A), but with new circuit constants. The cathode impedance Z_K is zero; the plate load Z_L is replaced by Z_o' (which combines the effects of plate resistance R_P, degeneration across Z_K, and plate load impedance Z_L); and μ is replaced by $-A'$.

The final portion of the procedure is to add the plate-to-grid voltage feedback, making the circuit the same as (A), *Fig.* 3, which can then be reduced to one of its simpler forms such as (D) or (E) of *Fig.* 3.

In all of the previously mentioned circuits the stray circuit capacitances are combined whenever possible into the impedances shown; otherwise they are neglected. For example, grid-to-plate capacitance can become a parallel element in Z_2.

The practical advantage of using a selective feedback amplifier over a conventional amplifier followed by an interstage equalizer is immediately evident from a comparison of (A) and (D) of *Fig.* 3. In the former case, the tube has to supply only the output voltage E_o while in the latter case, the tube has to supply several times E_o to make up for loss in the equalizer. Operation at a lower level causes the tube in the feedback amplifier to have less harmonic distortion by a factor of several times. In addition this lower distortion is further reduced by feedback. The internal impedance Z_o' of the feedback amplifier is likely to be lower than that looking back into the equalizer, which has to be kept at a high impedance level in order that the tube will have a sufficiently high plate-load impedance for low-distortion operation. Hence the feedback amplifier has greater freedom from the effects of external loads.

The disadvantages of using a feedback amplifier whose feedback varies with frequency response is more dependent upon the gain of the tube and may change with age. The response, however, can be stabilized to any desired degree by using enough feedback.

Effect of a Small Amount of Feedback on Beam Power Amplifiers

Circuit (B) of *Fig.* 1 and the related formulas show the effect of a small amount of feedback on the performance of a pentode or tetrode power amplifier. Without feedback, an 8-ohm loudspeaker may look back into as much as 80 ohms internal impedance due to the high plate resistance of the pentode. This means that if the load impedance were disconnected the output voltage would rise 20.8 db. If we were to apply just 6 db negative voltage feedback measured with the load connected, the loudspeaker would look back into something less than 8 ohms. This would be true even if the loudspeaker had originally looked back into 80 megohms.

The reason is plain from observation of the shunt impedance $Z_o/-A_o\beta$. (The $-A_o\alpha$ and α/β impedances are zero.) When negative voltage feedback is applied it is the loading effect of this impedance that reduces the output voltage. To reduce the output voltage to one half its value before feedback the value of this impedance must be equal to Z_o in parallel with Z_L. Therefore, with 6 db of feedback the loudspeaker looks back into less than its own impedance. This is because 6 db feedback with the

[*Continued on page 42*]

Expressions for the Reduction of Distortion and Output Impedance in Terms of db of Feedback

WILLIAM J. KESSLER* and SYDNEY E. SMITH*

The authors simplify the calculation of amplifier characteristics by employing easily measured parameters.

DURING THE PAST DECADE, it has become increasingly common to express the degree of inverse feedback employed in audio output amplifiers in terms of the gain reduction due to the addition of the feedback loop rather than the feedback factor $A\beta$. In many feedback applications the value of β cannot be readily determined unless the feedback signal is derived from a divider network where the values of all the impedances are known. In contrast, the degree of inverse feedback expressed in decibels may be readily determined simply by measuring the reduction in output level due to the addition of the feedback loop. This measurement may be made at any frequency; however it should be noted that the expressions for the reduction of distortion and output impedance are usually applicable only for the frequency corresponding to a single measurement, or the frequency range over which the measured gain reduction is substantially constant. Accordingly, it appears desirable to rewrite the well-known expressions for the reduction of distortion and output impedance due to the use of negative voltage feedback to eliminate the often indeterminate $A\beta$.

The conventional expression for the effective output impedance of a power amplifier[1] incorporating negative voltage feedback is:

$$R_o = \frac{R_p}{1 - \mu A_1 \beta} \qquad (1)$$

where R_p is the plate resistance of the output stage without feedback, μ the amplification factor of the output tube, A_1 the voltage amplification included between the feedback point and the grid of the output stage and β is the feedback fraction expressed as a decimal less than one. A similar expression for the reduction of distortion due to the use of negative voltage feedback is:

$$D' = \frac{D}{1 - A\beta} \qquad (2)$$

where D is the total harmonic distortion in the absence of feedback, D' the residual distortion with feedback, and A the total amplification included within the feedback loop.

The net amplification of an amplifier incorporating negative feedback is known to be:

$$A' = \frac{A}{1 - A\beta} \qquad (3)$$

Expressing the change of amplification in terms of decibels yields:

$$db = 20 \log (1 - A\beta) \qquad (4)$$

Combining this equation with equation (2) yields the following expression for the residual distortion in the presence of feedback free of the feedback factor $A\beta$:

$$D' = \frac{D}{\log^{-1} (db/20)} \qquad (5)$$

where db is the degree of inverse feedback expressed in decibels and D the initial total distortion.

In a similar manner, combining equations (1) and (4) results in an expression for the effective output impedance also free of $A\beta$ as follows:

$$R_o = \frac{R_p}{1 + \frac{R_p + Z_L}{Z_L}\{[\log^{-1} (db/20)] - 1\}} \qquad (6)$$

where Z_L is the recommended load impedance and R_p the plate resistance of the output stage in the absence of feedback. In the event the voltmeter used for making the level measurements before and after the addition of the feedback loop is not calibrated in terms of decibels, the ratio of the two voltage readings may be substitued for $\log^{-1} (db/20)$ in equations (5) and (6).

It should be observed that the value of R_p published in the tube manuals is reliable only for the class of operation specifically stated. The values of R_p for class AB_1 and AB_2 are seldom given, particularly when cathode bias is employed, because the actual plate resistance varies throughout the audio cycle. Under such circumstances, a more reliable "average" figure may be calculated from the expression:

$$R_p = Z_L[\mu/A_o - 1] \qquad (7)$$

where Z_L and μ are as previously defined and A_o is the large-signal amplification of the output stage.[2] A_o may be obtained by dividing the peak voltage corresponding to maximum power output by the recommended grid bias. For push-pull operation the peak *plate-to-plate* voltage should be divided by *twice* the recommended grid bias.

The magnitude of the effective output impedance R'_o reflected to the secondary of the output transformer can be verified by a simple and straightforward method previously outlined by Richter.[3] This output impedance, in terms of the open-circuited and properly-loaded output voltage, is then:

$$R'_o = R_L\left[\frac{e_o - e_L}{e_L}\right] \qquad (8)$$

where R_L is the recommended load resistance across the secondary of the output transformer. A speaker can be employed as a suitable load; however, it is recommended that a noninductive resistance be employed to remove doubt regarding the value of R_L. It is observed that the reciprocal of the bracketed quantity in equation (8) constitutes an experimental determination of the damping factor (R_L/R'_o) of the output stage.

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[1] *Radio Engineers Handbook*, Frederick Emmons Terman, p. 402.

[2] For push-pull operation, Z_L, R_p, and R_o can be regarded as the plate-to-plate values.

[3] Walter Richter, "Simple method of determining internal resistance," AUDIO ENGINEERING vol. 32, no. 10, pp. 19–20, October 1948.

New York AES Meeting:

Demonstration Record Committee Presents List of Selections

At the first fall meeting of the New York AES group, R. D. Darrell, chairman of the Test and Demonstration Record Committee, presented a list of selected records deemed suitable for demonstrating the performance of home music systems. Many of the choices were played on Mr. Darrell's own system, and brief descriptions of the music and what the records were intended to demonstrate were given. Selections ranged from full orchestra to individual instruments, from heavy classics to popular. Mimeographed lists of the records were presented to all present.

Square Wave Testing Simplified

HAROLD E. BRYAN*

The determination of the practical response limits of an amplifier is reduced to a few simple statements relating to the reproduced wave shape from a given square-wave frequency.

Ask the average engineer why he doesn't use square waves in making tests of an amplifier and he will probably say something like, "Square waves? Oh yes. They make those pretty pictures on the 'scope, and I always wonder what they mean. It's a waste of time—I'll run the curves." Of course, running the curves point-by-point is perfectly legitimate, and is highly desirable in some cases.

But square waves do have their place in testing equipment. They make it possible to obtain the necessary information on frequency and phase response of the amplifier quickly and with reasonable accuracy. Nor is the equipment expensive or hard to build—a good "square-waver" can be constructed very simply.[1] In addition, square waves will give information on the transient response of the amplifier that cannot be obtained from point-by-point curves. Less testing time is required than it normally takes to obtain one or two points on the usual curve.

Single-Stage RC-Coupled Amplifiers

Since no matter what type of coupling is used it involves time constants, the following analysis is based on the *RC* coupling.

At low frequencies, the amplifier is essentially a high-pass device, as illustrated in *Fig.* 1. It has often been stated that a square wave test provides no information on the characteristics of the amplifier at frequencies below the square wave fundamental. This is not strictly true. According to Fourier's theory, a symmetrical square wave contains a sinusoidal fundamental, at the repetition rate of the rectangular wave, and odd harmonics thereof. On the face of things it might therefore be said that since there are no frequencies involved which are lower than the fundamental of the test wave, there can be no information available about the performance at such lower frequencies.

A look at the coupling circuit from another angle, however, will show that there are indeed possibilities for lower-than-fundamental information. The ideal symmetrical square wave rises instantaneously to its maximum value, remains at that point for one half its period, and then drops immediately to its maximum negative value, where it remains for the duration of the cycle. In order for the amplifier to pass the wave as it is generated — remember we're considering low frequencies now—the coupling circuit must pass the flat top of the wave without alteration. This will be possible only if the time constant of the circuit is long compared with the time of the flat top. If this is not true, the top will slope off instead of remaining at a constant value.

Suppose it is assumed that if the top slopes down to no less than 95 per cent of the maximum value the response is sufficiently good. Let's see what this would mean in terms of the amplifier.

If a d.c. voltage is applied to the coupling circuit, which is essentially what is happening in the flat top of the wave, the voltage across the resistor will be determined by the equation

$$e_o = E\epsilon^{\frac{-t}{T}}$$

where t is the time at the point of measure

T is the time constant of the circuit.

In an *RC* circuit the time constant is equal to the product of resistance and capacitance. In the example above, where the final voltage is 95 per cent of the maximum,

$$e_o/E = 0.95 = \epsilon^{\frac{-t}{T}}$$

whence $t/T = .051$

This simply says that in order to meet the requirements set up the time constant of the circuit must be 1/.051 or 19.5 times the flat-top time, which is t in the equation.

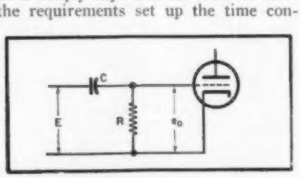

Fig. 1. Simplified equivalent circuit of amplifier at low frequencies.

From the information so supplied we can determine the frequency at which the response is down 3 db, assuming normal phase shifts, and in general the response at any other frequency in between if desired. In this type of circuit the frequency for 3-db attenuation is that at which the reactance of the capacitor equals the coupling resistance. That is,

$$f_o = \frac{1}{2\pi RC} = \frac{1}{2\pi T}$$

From above, $T = 19.5t$

$$= 9.75(2t) = 9.75/f$$

where

t is the half-cycle, or flat-top time

f is the frequency of the square wave

Then, with this information, by substitution the 3-db frequency

$$f_o = \frac{1}{2\pi T} = \frac{1}{2\pi\left(\frac{9.75}{f}\right)} = \frac{f}{61.3}$$

In other words, the frequency for 2 db attenuation is obtained by dividing the 95 per cent slope square-wave frequency by 61.3.

At a frequency approximately equal to one-tenth the applied frequency (roughly six times the 3-db frequency) the reactance will be one-sixth the resistance of the circuit and the amplifier response will be down only 1.3 per cent.

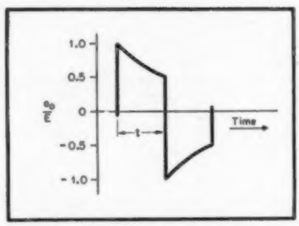

Fig. 2. Typical output signal showing square wave with 50 per cent slope.

Thus if the square wave obtained at the output of the amplifier is as good as pictured here, the amplifier—unless it is unusual in some other particular—will have good response down to one-tenth of the test frequency and will be down 3 db at approximately one-sixtieth of that frequency. The phase response will also be good over the same range.

Practical Aspects

While the foregoing analysis is perfectly valid, it may be slightly hard to apply, since it is difficult to determine accurately when a 95-per cent slope was realized. However, if the square wave

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[1] *See* Reference 1.

has a good flat top, it is apparent that the amplifier will be reasonably flat to one-tenth of the test frequency.

In order to make it easier to determine the actual frequencies involved, it is desirable to use something greater than a 95 per cent slope. It is also desirable to apply the square wave at a frequency where the response of the amplifier is still good. As a starter, let us assume that the test frequency is applied where the amplifier is down only 2 per cent.

Working backward from the fundamental equation for the amplifier response

$$e_o/e = 1/(1 - jf_o/f)$$

we find that for $e_o/e = 0.98$,

$$f_o = f/4.9$$

or the test frequency is 4.9 times the 3-db frequency. From this figure we can find the actual slope of the flat top. We know that

$$T = \frac{1}{2\pi f_o} = \frac{4.9}{2\pi f} = \frac{9.8t}{2\pi}$$

whence

$$t = 0.64T$$

Substituting this value in the equation

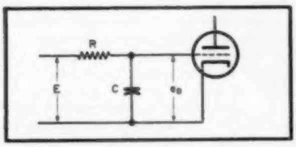

Fig. 3. Simplified equivalent circuit of amplifier at high frequencies.

for the voltage across the coupling resistance,

$$\frac{e_o}{e} = \epsilon^{-0.64} = 0.5275$$

So under these conditions the flat top will slope down to 52.75 per cent of maximum in the half cycle time. This is illustrated in *Fig.* 2. Thus in practice the frequency of the square wave is adjusted until a slope of approximately 50 per cent is realized. The 3 db frequency is then calculated by dividing the resulting test frequency by 4.9.

High-Frequency Response

The high-frequency response of the amplifier is handled in much the same manner, although it is somewhat easier. In this case, the coupling circuit is essentially that of *Fig.* 3, a low-pass device. The voltage output rises exponentially according to the relation

$$\frac{e_o}{E} = 1 - \epsilon^{\frac{-t}{T}}$$

where t is any time after application of the pulse. A typical case is illustrated in *Fig.* 4. When the measurement time is equal to the time constant of the circuit the output has risen to 63.7 per cent of its maximum value. At high frequencies, therefore, the leading edge of the wave will be rounded due to this exponential rise of voltage. By spreading the wave out on the scope it is possible to determine a 64 per cent rise time with reasonable accuracy in terms of the half-cycle time. From this the actual time in seconds is obtained.

At the high frequencies the amplifier is down 3 db when the reactance and resistance are equal. This is the same equation as before, but the resistance and reactance involved are different. Thus again

$$f_o = \frac{1}{2\pi T}$$

Since the time for 64 per cent rise of voltage is the time constant T, the 3 db frequency is easily calculated.

Multistage Amplifiers

Since the foregoing analysis is based

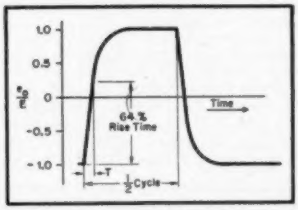

Fig. 4. Typical output signal showing deterioration of square wave due to reduced high-frequency response.

on a single coupling circuit, its value may be questioned. But it is the basis for the considerations in multistage amplifiers.

Consider a two-stage amplifier with identical coupling circuits, isolated by a tube. This can be considered at low frequencies as a single circuit whose time constant is one-half that of each of the original couplers. It would therefore appear that the 3-db frequency would be twice that of one stage, since the effective time constant is half as great as a single circuit. We find, however, that the response of the two circuits to sinusoidal signals is *not* down 3 db at this frequency. Instead,

$$f/f_o = 1.55$$

which means that the 3-db frequency is 1.55 times that of a single stage, instead of twice. The frequency calculated from the 50 per cent slope frequency, by dividing by 4.9, will not therefore be the true 3-db frequency. It is instead a frequency equal to twice the 3-db frequency for a single stage. To determine the value for the two stages, this latter value must be divided by two and multiplied by 1.55. Summed up, for a two-stage amplifier

$$f_{3db} = f \times \frac{1.55}{2 \times 4.9} = 0.158f$$

where f is the frequency for a 50 per cent flat-top slope.

For three stages, the considerations are the same. The ratio turns out to be 1.96 instead of 1.55 and the 3-db frequency

$$f_{3db} = f \times \frac{1.96}{3 \times 4.9} = 0.133f$$

For four stages,

$$f_{3db} = 0.116f$$

For more than four coupling circuits the same reasoning applies. However, the factor by which the 50 per cent slope frequency is multiplied approaches a limit and it is doubtful if the extra work is worth the effort. For example, on a test amplifier, which actually contained four coupling circuits plus an output transformer, the 50 per cent frequency was 350 cps. By assuming that the amplifier contained only two stages, the 3-db frequency was calculated to be 55.4 cps. For three stages it was 46.6 cps and for four stages, 41 cps. The true 3-db frequency, by measurement, was 43 cps. Thus little practical error is involved if the estimate of the number of stages is wrong and there seems to be no point in going beyond four stages.

The high-frequency response is analyzed in the same manner, but the calculations are somewhat more involved. It can be shown that the equivalent single stage, for a two-circuit amplifier, has a time constant 1.585 times that of each individual circuit. The frequency for 3-db attenuation of sinusoidal signals is 0.643 times that for one stage. Since the reciprocal of 0.643 is 1.55, there is not much point in attempting to obtain an accurate expression. If the difference is ignored the result is still within 2 per cent. This is closer than the time can be read on the oscilloscope screen.

Similar results are obtained for more stages. In the test amplifier, the 3-db frequency was calculated as 70 kc, and by actual measure was 65 kc.

Other Considerations

When transformers appear in the amplifier, as they often will, other things may have to be taken into account. These may or may not invalidate the results obtained by the above analyses, depending upon how good or how bad the transformers are. Generally speaking, if such tests are undertaken on an amplifier it is because the owner considers it to be a pretty good one and wants a "quick and dirty" method of finding out how good it actually is. With reasonably good transformers no particular trouble should be experienced.

Response peaks usually due to transformers will produce transient effects, appearing as damped waves on top of the square wave. These may make the high-frequency response determinations difficult. Another effect which may be noticed in some cases will appear the same but at a very low frequency. This will probably be due to insufficient damping of a loudspeaker load. It is doubtful if this will be experienced, however, since the test frequency probably will not be low enough to show it up.

[*Continued on page 46*]

More About Mismatching

ROBERT M. MITCHELL*

A discussion of the manner in which a change in the load presented to an amplifier can affect gain, frequency response, distortion, and other characteristics.

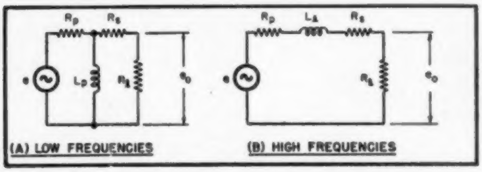

Fig. 1. Simplified equivalent circuits of output transformers at low frequencies (A), and at high frequencies (B).

ADVICE CONCERNING the matching of loads to audio amplifiers was provided in these pages some months ago.[1] The large number of questions about this problem shows it to be one of the major concerns of audio constructors. Many of these questions concern power output capabilities, and have been answered in the article cited. Many others, however, concern performance characteristics of the amplifier or system as a whole, aside from power capabilities. These are questions of quality rather than quantity, and involve frequency response, distortion, hum, damping, gain, and stability. These characteristics will each be briefly treated in respect to their relationships to load changes.

Damping

The damping factor of an amplifier is the ratio of the load resistance R_l to the plate resistance r_p of the output stage, both referred to the same side of the output transformer.

$$D = \frac{R_l}{r_p}$$

(1) Obviously, if a higher than rated load impedance is used, the damping is improved.

(2) If a lower load is used, the damping is poorer.

Frequency Response

Figure 1 shows the simplified equivalent circuits of an output transformer at low and at high frequencies. At (A), for example, the value of the primary inductance L_p is chosen by the designer so as to make the output e_o at a frequency f_L 3 db below its mid-frequency value when a load R_l is connected to the output. If the transformer is manipulated by mismatching so as to make R_l smaller, the frequency at which L_p will produce this same loss in output is reduced. Consequently, the low-frequency response is improved.

Just the opposite is true for the high-frequency end. Diagram (B) in *Fig.* 1 shows that as R_l is decreased, more and more of the voltage is developed across the leakage inductance L_p and less and less across R_l. Consequently, the high-frequency response is made poorer. The lumped primary resistances R_p and secondary resistances R_s are assumed to be small for both cases. We may summarize these results as follows:

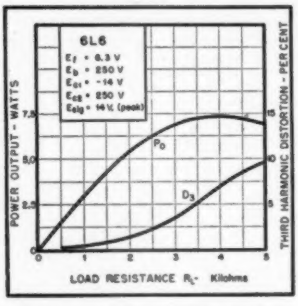

Fig. 2. Curves showing the effect of changing load resistance has upon power output and distortion in a typical beam power tetrode—the 6L6.

(1) Connecting a load impedance lower than the rated load shifts the frequency characteristic downward, resulting in better low-frequency response and poorer high-frequency response.

(2) Connecting a higher impedance shifts the frequency characteristic upward, resulting in poorer low-frequency response and better high-frequency response.

Distortion

If a push-pull amplifier is involved, as is almost always the case, the even-order harmonics of the output tubes appear considerably reduced in the output if not completely canceled. The third harmonic, however, is not reduced by push-pull connection, and consequently, must be considered when mismatching.

Figures 2 and 3 show the variation of third harmonic distortion as the load is changed for two representative types of tubes. The increase of distortion with load impedance shown in *Fig.* 2 for the 6L6 is typical of beam power tubes and pentodes. With triodes, however, the change is in the opposite direction, as *Fig.* 3 shows for the WE 300B. Designers sometimes take advantage of this relationship to reduce the distortion in triode amplifiers when the loss in power is not significant. It is often possible to obtain a considerable reduction in distortion with only a slight loss in power. This was done in the well-known Williamson amplifier, for example, where a plate-to-plate load of 10,000 ohms was used for tubes whose rated load as given by the manufacturer was much lower (4,000 ohms).

(1) Connecting a higher than rated load tends to increase distortion for beam power tubes.

(2) Connecting a higher load tends to decrease distortion for triodes.

The gain of the output stage is given by the relation

$$A = \mu \frac{R_l}{R_l + r_p} = \mu \frac{1}{1 + \frac{r_p}{R_l}}$$

The ratio of gains with different loads is then

$$\frac{1 + \frac{r_p}{Rl_1}}{1 + \frac{r_p}{Rl_2}}$$

[*Continued on page 54*]

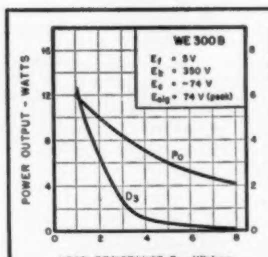

Fig. 3. Load resistance vs. power output and distortion for a typical triode—the 2A3.

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[1] S. J. White, "How far can I mismatch?" AUDIO ENGINEERING, Jan. 1951.

Audio—Big Business

LEON WARTMAN

From an unfamiliar word to a profession, to the Society, to the Audio Fair—Audio has become one of our fastest growing industries.

It probably is America's youngest industry and in spite of that has already grown to be a ¾ billion dollar enterprise. It's the "sound" industry. Its members call it "audio." The word "audio" is still described in modern dictionaries as an adjective but its followers refer to it as a proper noun, "Audio." It is defined as the science of the production and reproduction of sound through electro-mechanical techniques. It's the design, manufacture, processing, and distribution of equipment, and the actual playing back of recorded music, speech and other sounds. It's the production of equipment for making tape and wire recordings. It's the design, manufacture and sale of microphones, amplifiers, loudspeakers, and recordings. It is the putting together of these devices into an integrated system for the sheer pleasure and esthetic delight of listening to the supernatural reproduction of music. It even extends to other industries such as furniture, where thousands of cabinets are scientifically custom-made to contain this equipment most attractively. It is an industry that caters to the ears of lovers of music, from Bach to BeBop. The Audio Industry gives employment directly to an estimated 100,000 persons in the United States alone. No one can estimate the number of people who derive pleasure from the industry's efforts.

The Great Leveller

Rich man, student, and wage earner are on one level—and none objects—when they meet at the local equipment supply houses to see and hear the latest audio devices which are being offered for sale. There they find a certain camaraderie, a mutual and rabidly devoted interest where, surrounded by woofers, tweeters, pickups, turntables, tuners, amplifiers, equalizers, and recordings, they can express their personal preferences and discuss the relative merits of one device over the other. One debater may have an Audio outfit in his home costing thousands of dollars. Another, a youth still on a weekly allowance, may have, over a period of time, accumulated a hundred or so dollars worth of merchandise. One may have hired an Audio Consultant to design and construct the electronic portions and an Interior Decorator for the cabinets and loudspeaker box. The other may have designed his by copying from magazine articles, "horse-trading" for the components, hand-building and home-making what he didn't have the cash for. One is just as proud as the other and can justify the choice made for each unit of his Audio "system."

So enthusiastic are these Audio enthusiasts that several magazines completely out of the technical field are recognizing this growing factor of the buying public and are devoting new pages and sections to it.

Too, a new type of music critic has been created, one who not only must be qualified to comment on a recorded musical performance, but who can comment on the microphone placement, auditorium acoustics, and other technical aspects. This new critic revues the record *en toto* and, should he betray an unfamiliarity with the technical aspects, he might be swallowed up by a sea of indignant Audio enthusiasts, as well as by those among his readers who are professional musicians.

The AES is Formed

In 1948 a society of Audio enthusiasts was formed by a group of engineers, business men, an editor, and an attorney. They drew a constitution and became the Audio Engineering Society (AES) for the "diffusion and increase of educational and scientific knowledge in Audio Engineering, the promotion and advancement of this science and its allied arts in both theoretical and practical application . . . the encouragement of the interchange and intercourse of ideas. . . ."* A Board of Governors was created and the temporary officers appointed. Within less than a year, a general election was held and officers were democratically installed by direct-mail ballot. The society now has seven active sections holding monthly meetings in four states. Ten foreign countries are represented in the AES Directory of Members.

In addition to the monthly meetings of the local chapters, the Society holds a national meeting once each year. The first convention, held in October of 1949 at the Hotel New Yorker, lasted three full days and drew so enthusiastic a response that the AES immediately reserved space for October 1950 for the second annual convention. As is customary for convention times, a manufacturers' exhibit of equipment is held concurrently. The exhibit held concurrently with the AES convention is called the Audio Fair, and is managed by Harry N. Reizes, a member and general counsel for the Society.

In 1949, the year of the first convention, the manufacturers responded with mild enthusiasm, stating that they had to attend too many conventions which already stretched the budget. Yet enough manufacturers responded to lease two-thirds of the rooms on the sixth floor of the Hotel New Yorker for the three day convention period. The AES convention and the Audio Fair were both freely publicized by the industry in a joint effort. Paid advertisements were taken in the trade press by the Audio Fair management. The AES membership responded loyally. But the biggest surprise of all came from the general public. Students came in groups, Audio enthusiasts and the inevitable convention go-ers came singly or brought friends who quickly caught the enthusiasm and, in turn, became Audio enthusiasts.

In October of 1950, the second annual convention and the Audio Fair were again held at the Hotel New Yorker. Publicity was extended to the daily newspapers, literary magazines, and the radio. So many manufacturers, publishers, and distributors of audio components expressed their desires to participate in the Audio Fair that the entire sixth floor and half of the fifth floor had to be leased. Attendance was double that of 1949 and enthusiasm increased immeasurably.

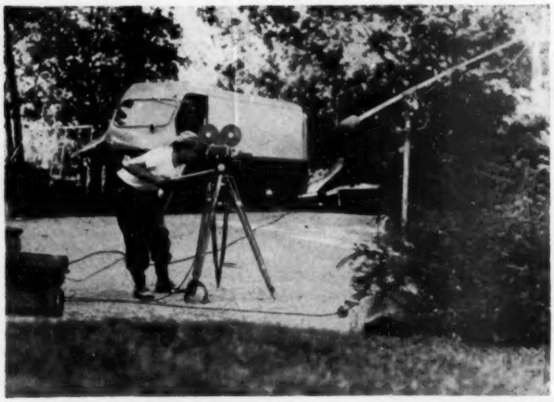
The 1951 Convention

The third annual convention of the AES and the Audio Fair are to be held this November 1, 2 and 3 at the Hotel New Yorker. It is expected that the attendance will double that of 1950 and the visitors will see the exhibits of about 200 members of this 750 million dollar infant industry, still growing apace with its younger and bigger brother, Television. The visitors will see items ranging in cost from a few pennies to thousands of dollars. The manufacturers', publishers', and distributors' attendants will discuss and demonstrate their wares in their private rooms to an excited public for three days with little more than time out for coffee and doughnuts. This time the entire fifth and sixth floors of the Hotel New Yorker have been leased by the Audio Fair Management.

A friendly sort of rivalry for the visitor's attention has grown among the exhibitors. All sorts of novel gimmicks and wholesome attention-getters are used. One enthusiastic exhibitor is publicising a "Golden-Ear" contest. Each visitor to this exhibitor's room will be given a hearing quality test with a Bell Laboratories "Audio-Meter." The results will be recorded on a "Golden-Ear" lapel tag for the visitor and in a scoring book retained by the exhibitor. This will continue during the three days and valuable prizes of Audio equipment will be given to about twenty of those who have hearing which is considered closest to the ideal.

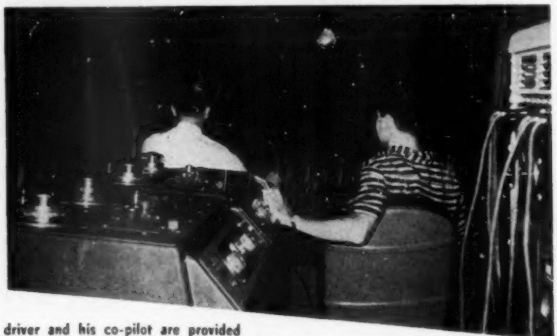
Exhibitors who complained they were already attending too many conventions have dropped out of others in favor of the low-cost Audio Fair which gives its small profits, after all salaries and expenses are deducted, to the Audio Engineering Society for the "encouragement of the interchange and intercourse of ideas."

* AES Constitution; excerpt from Article II, "Objects."

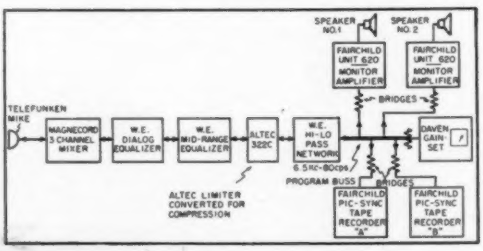


C. Robert Fine, designer and builder of the "location" unit, is shown using the synchronous 16mm magazine loading Maurer camera which is being used for color work. A Telefunken microphone is at the end of the boom. The microphone and camera are equipped with 200′ of extension cables. Since the recording truck can operate 600′ from the generator trailer, it is thus possible for the microphone to be as far as 800′ from the generator. This is quite useful for work done in the narrow winding streets which are characteristic of numerous historical European towns and villages. Remote controls enable one man to operate all equipment that is inside the truck while he is at the camera or microphone boom.

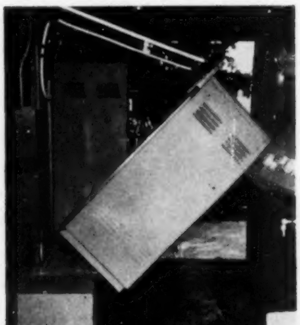
The microphone and audio mixer is a Magnecord PT6-P. It can be operated inside or outside the truck. Below the Magnecord mixer can be seen a small Jensen bass-reflex baffle equipped with long extension lines so that it can be placed near the subject being photographed.



The driver and his co-pilot are provided with seats at the front cab of the truck. The seats fold forward and out of the way to allow as much floor space as is possible. The entire truck and trailer can be operated while in motion.



For recording sound tracks, all equipment is normalled through jacks. Inputs and outputs of the separate units in the system can be lifted and multiples are also provided. For wide-range recording, the dialog equalizer and the mid-range equalizer are "patched around."



The two racks of equipment shown in the block diagram are mounted against the bulkhead opposite the Magnecord mixer location. The racks are hinged at the bottom and secured at the top with wing nuts and bolts so that they can be made to swing forward and rest against the restraining chains, exposing their interiors for service and inspection.

All sound tracks are recorded on two Fairchild Pic-Sync Magnetic Tape Recorders, operating simultaneously for an original and a safety. The monitor speaker is secured to the bulkhead of the truck and just above the Fairchild Tape Recorders. The tape equipment is mounted on Barry shock-mounts. Heavy coil springs, secured to the outsides of the recorder cabinets, insure that they will not "roam about" the floor of the truck while travelling. At the same time, these springs do not inhibit the effectiveness of the shock-mounts.

Meet the Cinécruiser

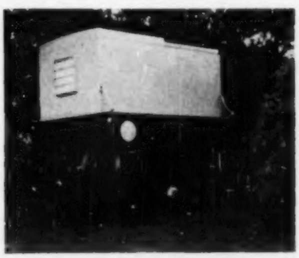
New mobile location unit provides synchronous magnetic tape facilities for recording motion picture sound tracks.

MANY MEMORIALS to great people and great places have been carved in granite, put to canvas, and in other ways immortalized. Too often, it has been complained, they are artists' conceptions and usually idealize the mien, pose, poise and relative stature of their noble subjects. But no medium portrays as realistically as does the motion picture camera. Nothing else preserves the great mortals for posterity more completely than does the motion picture with its sound track.

The Jerome Hill Foundation, a philanthropic organization, is sponsoring a project to immortalize the great through the medium of cine-sound. Toward this end, the foundation engaged the services of C. Robert Fine, a prominent audio engineer. Mr. Fine's assignment was to design and construct a completely mobile "location unit." With a thirty day deadline, the unit described and illustrated on these pages was designed and constructed, laboratory and road tested, and driven aboard a freighter bound for Europe and its first assignment. By the end of October 1951, both Mr. Fine and the "location" unit will have returned to the States and left for their second "assignment for immortality" in California.

The "location" unit (it hasn't been christened with a name as yet) consists of a 1-ton, 6-cylinder Chevrolet truck with an aluminum body. It is equipped with an extra gas tank to take care of those long stretches between European refuelling stations. All of the operating equipment is contained inside the truck which has sufficient space for two operators to move about without crowding or stooping. There is adequate floor space for sleeping cots, in case of emergencies.

The meter panel monitors both splits of the power line feed from the trailer. Each line is metered for voltage, current load and frequency. Should the power line frequency fall below 59 cycles, an alarm is tripped which warns the operator that there is danger of out-of-sync operation. There are twelve main-power outlets. Each is protected by an individual magnetic circuit breaker. By selecting the proper outlets, or by manipulating the circuit breakers, the loads on the split-line feed can be kept in balance, one side of the line with the other. For camera, truck and trailer intercommunication, a Masco system is provided.



The two wheel trailer contains the power generating equipment and can be quickly hitched or unhitched by one man. It is equipped with electric brakes and signal lights. The louvres, which can be seen on the front of the trailer, pivot freely. Behind them is a large ventilating fan. When the generator is started, power is supplied to the fan motor and the louvres open automatically and are raised by the air stream. This makes certain that they will be closed when the equipment is idle, keeping out dust and rain.

The power generator, contained inside the trailer, is a 10wk Kohler driven by a 4 cylinder gasoline engine. The trailer carries its own gasoline supply tank. The output of the generator is 220 volts a.c., 60 cycles. The 220 volt line is split to 110-0-110, so that all American and some of the European equipment encountered can be operated from the one source. The ventilating fan can be seen just above the generator, at the rear. Six hundred feet of cable, in six 100' lengths, enable the generator to be adequately sound-separated from the truck.

Simple Attenuator Calculations

JACK D. GALLAGHER*

Using only algebraic methods, the author presents a simple approach to determining resistor values for T pads.

DESIGN OF ATTENUATORS for the reduction of voltage, current, or power in pre-determined amounts is often necessary in the adjustment of audio systems, impedance matching circuits, and other applications.

One of the most commonly used attenuators is the "T" pad as shown in *Fig.* 1. The computations for solving the values of the resistive components of the "T" pad involve the use of hyperbolic functions as indicated by the associated formulas.

The value of θ is the value of the image transfer constant, or the loss in the network in nepers—this quantity being equal to the loss in decibels divided by 8.686.

There are other formulas which can be used to solve for the resistive components of the network, but they also involve the hyperbolic functions of the image transfer constant. Perhaps the only cumbersome feature of these formulas is that a table of hyperbolic functions must be used in their solution, or a vector slide rule must be used if one is available. However, this is not the only objectionable feature of these formulas, for there is no method of predetermining whether or not one of the resistive elements will become less than zero with a desired loss until the formulas in *Fig.* 1 have been solved. Thus, effort is wasted in computing values for a non-existent T pad.

Algebraic formulas for the solution of a T-pad network are shown in *Fig.* 2.

In the formulas for c and b, the value of P is always less than 1, and is equal to the antilog of the quotient of the desired loss in decibels divided by 20, or

$$P' = \text{antilog}_{10}\left(\frac{db}{20}\right).$$

If the right side of the equation for P' comes out greater than 1, the reciprocal of P' is used as P in the above formulas; if P' is less than 1, use P' for P in the formulas. Thus, if the desired loss is 40 db, P would be 0.01, and if the desired loss is 10 db, P would be .316.

It can be shown that a simple approximate formula for determining the least loss for which a T pad can be designed is given by the following expression:

$$\textit{Least loss in db} \cong 20 \log_{10}\left[0.5\sqrt{\frac{Z_1}{Z_2}}\right]$$

If the quantity in the brackets is less than 1, use the reciprocal of this value in solving for the least loss.

Examples

The use of the formulas can be illustrated by choosing a practical example. Suppose that $Z_1 = 225$ ohms, $Z_2 = 625$ ohms and the required loss is to be 25 db. The first step in the solution is to determine if the T pad can be designed for a 25 db loss.

Using the approximate formula previously given for determining the least loss in db, we find it to be

$$db \cong 20 \log_{10} 0.5\sqrt{\frac{225}{625}}.$$

Since the value of the constant and radical expression is less than 1, the reciprocal must be used; thus

$$db \cong 20 \log_{10} 2\sqrt{\frac{625}{225}}$$
$$\cong 10.4$$

Since this value is less than 25 db, the design can continue with the assurance that one of the resistive components of *Fig.* 2 will not become less than zero. The exact value of the least loss as computed by a slightly more cumbersome formula was found to be 9.54 db.

Continuing with the design, the value of P in the formulas for c and b is determined.

$$P' = \text{antilog}_{10}\left(\frac{25}{20}\right)$$
$$= 17.75.$$

But, since P' is greater than 1, the reciprocal must be used; that is, $P = 0.0564$. Substituting this value in the algebraic formulas for c and b, the values of the resistive components in the network of *Fig.* 2 are: $c = 42.8$ ohms, $b = 600.2$ ohms, and $a = 183.6$ ohms.

If, in the example, the required loss were 8 db, the solution of the approximate formula for the least loss in db would indicate that a T pad could not be used with the impedances in the example, and no further calculations need be made.

If the designer is frequently confronted with T-pad problems, it is convenient to make a table of least losses from the approximate formula previously given so that useless computations will be avoided. If the exact least loss is desired, the following formula can be used to compute this loss.

$$\textit{Least loss in db} = 20 \log_{10} \frac{\sqrt{Z_2} + \sqrt{Z_2 - Z_1}}{\sqrt{Z_1}}.$$

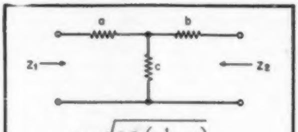
In this formula, Z_2 is the larger of the two impedances.

The use of hyperbolic tables or a vector slide rule is not necessary in the foregoing discussion; however, a slide rule containing enough scales to solve square roots, determine logs, and to accomplish simple multiplication and division is almost a necessity.

If a T pad is designed using the value of least loss as given by the formula above, the resulting network will be an L pad which will match the terminal impedances.

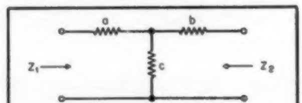
REFERENCE

F. E. Terman: *"Radio Engineer's Handbook,"* McGraw-Hill, New York.



$$c = \sqrt{Z_1 Z_2\left(\frac{1}{\tanh^2\theta} - 1\right)}$$
$$b = \frac{Z_2}{\tanh\theta} - c$$
$$a = \frac{Z_1}{\tanh\theta} - c$$

Fig. 1. Formulas for determining resistor values for T pads, using hyperbolic functions.



$$c = \frac{2P\sqrt{Z_1 Z_2}}{1 - P^2}$$
$$b = \frac{c\sqrt{Z_2}}{P\sqrt{Z_1}} - c - Z_2$$
$$a = Z_1 - \left[\frac{c(b + Z_2)}{c + b + Z_2}\right]$$

Fig. 2. Formulas for determining resistor values for T pads, using only the impedances and the term P which is derived from the pad loss.

Neat Suite

The extent to which high-quality audio has achieved recognition in the business world is well exemplified in the new Manhattan offices of MacManus, John & Adams, Inc., Detroit advertising agency.

Designed and built under the direction of v.p.-manager Ernest A. Jones, an audio hobbyist himself, the suite represents tasteful coordination of esthetic and functional influences with superb reproduction of sound for auditioning purposes.

Equipped with Altec Lansing amplifiers and speakers, Rek-O-Kut turntables, and Pickering reproducers, the installation offers a graphic glimpse of what may be expected among prime amenities in the office of tomorrow.

* 5438 McCommas Ave. Dallas 6, Texas.

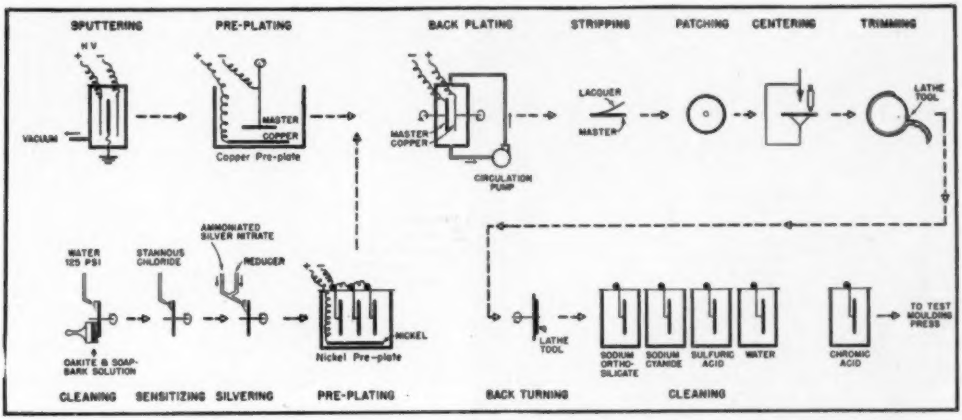


Fig. 1. Flow chart for record processing in modern plant equipped for high-quality record or transcription manufacture.

Technique of Record Processing

LEWIS S. GOODFRIEND*

A review of the methods employed in the making of high-quality transcriptions, from lacquer master to finished platter.

THE GENERAL TECHNIQUE for making modern phonograph record matrices has been discussed at length, and its application in one of the country's most modern plants will be described here.[1] The key to high-quality phonograph reproduction is in the manufacture of phonograph records. Bad recordings and pressings can never be made to produce good quality. The discs even when perfect have already lost some detail, and in order to produce as fine a disc as possible great care must be taken.

Lacquer masters or wax masters are received at the pressing plant in dust-proof boxes which are not opened until the disc is ready for metalizing. The operator removes the disc from the box, inspects it, and if it is without defects it is processed. The plant of the K. R. Smith Division of Allied Record Mfg. Co., to be described here, uses both gold sputtering and silvering processes for metalizing. Since the former is used almost nowhere else in this country it will be considered first. The entire processing operation is diagrammed in *Fig.* 1.

The object of the metalizing is to produce a metallic surface on the lacquer master so that a heavy metal backing may be plated on the impression of the grooves. After inspection in an air conditioned sputtering room the lacquer master is placed in the sputtering chamber, *Fig.* 2, which is then sealed and evacuated. When the proper vacuum is reached the high voltage is turned on and the lacquer is sputtered with a layer of gold only three molecules thick. This process takes from 12 to 20 minutes depending on the lacquer volatile content. After the sputtering is completed the voltage is removed and the pressure in the chamber returned to atmospheric. The disc is then removed and immediately placed in the copper pre-plate room. The pre-plating is done in a tank in which the gold-plated master is the cathode and copper bars in the bottom of the tank form the anode. The disc is washed with distilled water just

Fig. 2. Operator removes the gold-sputtered master from one of the three vacuum sputtering units.

* *404 Riverside Dr., N. Y. 25, N. Y.*

[1] Harold Harris, making phonograph record matrices." AUDIO ENGINEERING, July 1948, p. 14.

Fig. 3. K. R. Smith demonstrates the washing of a master between the sputtering and pre-plating processes.

Up to the end of the pre-plating operation the processing has included metalizing the original lacquer master and adding thicknesses of various metals. At this point the success or failure of the plating operations is determined. The lacquer master and the metal impression are separated at the stripping table. This is a hand operation and depends on the skill of the workmen. When the metal layers are stripped off, the soft gold or silver layer is outermost and any sliding of the lacquer over the soft metal may damage the raised groove impressions of the *metal master*. To strip the master, a knife blade is inserted between the lacquer and the metalized layer and carefully used as a lever to pry the two masters apart. In a pressing plant the metal master is known as *the master* while the lacquer original is known as the *lacquer master*. The master has raised impressions of the original recorded groove surfaces, and inspection of the master at this point tells whether the metalizing and pre-plating operations were successful.

prior to being immersed in the acid copper bath, *Fig*. 3, and is rotated in the bath in order to increase the chemical activity. The current density during this pre-plating is low, about 25 amperes per square foot. The thickness of the pre-plate is about .0015 in., and is deposited in about 30 minutes. Following the pre-plating the disc is placed in one of the high-speed platers which deposits a .055-in. back plate of copper in about four hours at a current density of at least 250 amperes per square foot, requiring about 1200 ampere-hours. The bank of nine high speed platers is shown in *Fig*. 4. The heavy braided copper leads carry the high plating current while the pipes permit high-speed circulation of the plating solution.

Silvering

When the process reaches the back-plating stage both silvered and gold sputtered masters follow the same processing, as the flow chart indicates. So a quick review of silvering will show what has been happening to the discs that customers ordered processed by the silvering method.

On passing inspection, the disc is scored on the back through to the metal base, in a circle about a quarter of an inch from the edge, and the edges are scraped free of lacquer. By doing this, the operator assures that the silver film will not peel near the edge. Then the disc is placed on a slowly turning table in a plating booth and degreased with a solution of soap bark and Oakite and washed in a water spray under 125 psi pressure. The lacquer surface is sensitized by a spray of stannous chloride which slightly penetrates the surface. After further washing the disc is sprayed by a dual jet nozzle, *Fig*. 5, which simultaneously feeds ammoniated silver nitrate and a reducing agent, either formaldehyde or dextrose. When they come in contact with the sensitizer they form a very thin layer of metallic silver on the lacquer surface. In spraying any of the solutions the spray is always done from the outside in, in order to obtain good bonding at the edges.

Following the spraying and final washing, the discs are placed vertically in a nickel pre-plating tank. This tank does not have rotating electrodes, because too much agitation may cause separation of the silver film from the disc. After 15 to 20 minutes in the pre-plating bath, the disc is ready for the high-speed back plating operation. *Figure* 6 shows the operator closing the first three high-speed platers after reloading. The solid copper anode may be seen in the plater at the left.

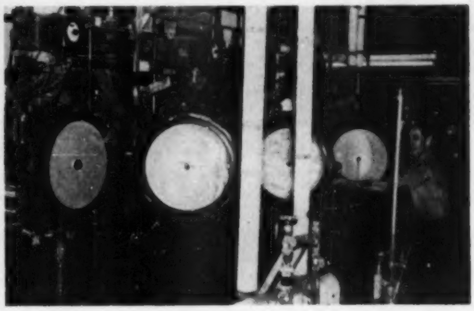
Fabrication

Following stripping and inspection, the original center hole of the disc is filled in with a patch. Usually the plating around the hole has not been even so a small section is cut away and a small piece of copper soldered into the center in its place. Even if the original hole had been reproduced accurately it is usually not desirable to use it. Many recording tables have worn or undersized center pins, and manufacturers allow a tolerance in the size of the center hole of the lacquers that they supply. These two factors combine to permit an original center hole with an eccentricity of .003 to .004 in. An accurate center is located on a centering table by rotating the disc and watching the grooves with a mi-

Fig. 4. Back view of the high-speed plating machines. These motors rotate the solid copper anodes, while similar motors on the front of the machines rotate the master discs. Note the heavy braid leads necessary to carry the high plating current.

Fig. 5 (left). Silvering a master with a dual-jet nozzle.

Fig. 6 (below). Operator preparing to close three high-speed platers.



croscope. The edge of the disc is tapped lightly until one groove spiral may be traced each revolution. The punch is then operated and a new and accurate center is in the master.

After centering, the master is placed on a trimming turntable, *Fig. 7*, which has a tight fitting center pin. A circular knife blade is closed on the rim of the disc and the disc turned slowly. With each revolution the knife pressure is increased until the rim is cut. This provides the edge of the master which is gripped by clamps in the molding presses. All that remains now is the back turning. This operation illustrated in *Fig. 8* is performed on a lathe which has a rubber sealing ring on a soft paper-faced vacuum chuck. The rubber prevents air leakage and the paper prevents damage to the groove faces while the vacuum holds the master tightly without clamps or screws. The back of the master is turned until the total thickness is forty thousandths of an inch. It is then ready for the final set of chemical baths required to plate a thin layer of tough chromium over the gold or silver face of the metal master. The chromium is strong enough to resist plastic flow under the high pressures in the stamping press.

Chrome Plating

After the fabrication has been completed the disc must be thoroughly cleaned. First grease is removed in an electric caustic bath of sodium orthosilicate. It then goes to a sodium cyanide dip which neutralizes the alkali and brightens the gold. After this it is given a sulfuric acid dip that precludes contamination of the chromate both by cyanide or alkali. Following the chemical treatment the master is washed and placed in the chromic acid plating solution. It is usually mounted with another disc for this part of the process. Two sixteen inch masters are first given a 1500-amp. "jolt" for 15 seconds, followed by nine minutes at a current of 600 amps. When the discs are then removed, washed, and dried, they are finished masters.

When it is desired to make more pressings than a single stamper can produce, a *mother* is made. The mother is a metal replica of the lacquer master. That is, the grooves are now in the disc rather than raised from the surface as in the master and stamper. In this plant the method of producing mothers is to make a test pressing from the master, and on approval of this pressing repeat the process starting with the master. That is, the master is gold sputtered over the chrome on the master. The rest of the mastering process is followed giving a mother which separates from the master between the gold-chrome interface. The process may be repeated starting with the mother this time and ending with a stamper. Several stampers may be made from each mother.

Another more common process to obtain mothers is to remove the silver from silvered masters by a chromic acid bath. This leaves the nickel surface. The nickel surface is now cleaned and treated by a separating agent or stripping solution, usually sodium or potassium dichromate. This *pacifies* the nickel and forms a thin crystalline oxide which is

[*Continued on page 46*]

Fig. 7 (above). Trimming of the master follows accurate locating and punching of center hole.

Fig. 8 (right). A vacuum chuck is used to hold the master during the back-turning operation.

AUDIO engineering society

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The Measurement of Audio Volume

H. A. CHINN*

Part II—A comprehensive discussion of the problems involved and the instruments employed to indicate program level and sine-wave tones in broadcast and recording circuits.

A THOROUGH COMPREHENSION of the connotations of the term "reference volume" is fundamental to any studio engineering endeavor. Unfortunately, experience has shown that this subject is often completely misunderstood. It is hoped that the following will dispel the vague understanding that sometimes surrounds this simple subject.

It is important to appreciate that reference volume is a practical and useful concept, but one which is quite arbitrary and not definable in fundamental terms. As already mentioned, it cannot be expressed in any single way in terms of the ordinary electrical units of power, potential, or current. Reference volume is describable only in terms of the electrical and dynamic characteristics of an instrument, its sensitivity as measured by its single-frequency calibration, and the technique of reading it. In other words, reference volume may be defined as that level of program which causes a standard volume indicator, when calibrated and used in the accepted way, to read zero VU.

The sensitivity of the standard volume indicator is such that reference volume corresponds to the indication of the instrument when it is bridged across a 600-ohm resistor[3] in which is flowing one milliwatt of sine-wave power.

It is especially cautioned that *reference volume should not be confused with the single-frequency power* used to calibrate the zero volume setting of the volume indicator. If a volume indicator is calibrated so as to read zero VU on a sine wave power of, say, one milliwatt in a stated impedance, a speech or program wave in the same impedance whose intensity is such as to give also a reading of zero VU will have instantaneous peaks of power which are several times one milliwatt and an average power which is only a small fraction of a milliwatt. It is therefore erroneous to say that reference volume is one milliwatt.

Moreover, it should be emphasized that although it is convenient to measure the performance of amplifiers and systems by means of single frequencies there is no *exact* universal relationship between the single-frequency load-carrying capacity indicated by such measurements, and the load-carrying capacity for speech and program waves expressed in terms of volume level. This relationship depends upon a number of factors such as the rapidity of cutoff at the overload point, the frequency bandwidth being transmitted, the quality of service to be rendered, and similar factors.

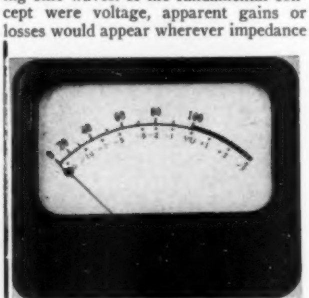
The question may well be raised why reference volume has been related to a calibrating *power* rather than to a calibrating *voltage*, inasmuch as a volume indicator is generally a high-impedance, voltage-responsive device. A reference level could conceivably be established based on voltage and the unit of measurement might be termed "volume-volts." However, volume measurements are a part of the general field of transmission measurements, and the same reasons apply here for basing them on power considerations as in the case of ordinary transmission measurements using sine waves. If the fundamental concept were voltage, apparent gains or losses would appear wherever impedance transforming devices (such as transformers) occur in a circuit. This difficulty is avoided by adopting the power concept, making suitable corrections in the readings when the impedance is other than 600 ohms.

* *Columbia Broadcasting System, 485 Madison Ave., New York 22, N. Y.*

[3] A standard impedance of 600 ohms was chosen originally since, keeping in mind the telephone plant, there was more audio equipment designed to this impedance than to any other.

Courtesy General Electric Co.

Fig. 2. The "A" type standard volume indicator scale emphasizes the VU markings and has an inconspicuous voltage scale. This type of scale is commonly used for transmission measuring sets.



Courtesy General Electric Co.

Fig. 3. The "B" type standard volume indicator scale emphasizes the percentage scale. This scale is used extensively for program transmission applications.

Volume Measurement Terminology

(a) VU. The terminology that is used to express volume measurements was created to avoid confusion as to the type of volume indicator used and the reference level. The term "VU" (pronounced "vee-you") is used; the number of VU

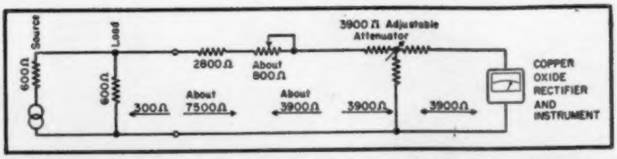


Fig. 4. The basic circuit for the standard volume indicator has an input impedance of 7500 ohms. For maximum sensitivity the loss in the adjustable attenuator is reduced to zero, but in order to maintain proper dynamic characteristics the indicating instrument itself must always face approximately 3900 ohms.

being numerically the same as the number of *db* above or below the reference volume level. The use of this term is restricted to the ASA standard volume indicator described herein. A volume level reading can be correctly expressed in terms of VU only when it has been made with an instrument having the electrical and dynamic characteristics described.

(b) DBM. For steady-state measurements a reading in "VU" would denote a specific single-frequency audio power, for dynamic program indications "VU" denotes only a volume level. This dual meaning of "VU" is avoided by the use of the term *"dbm"* for all steady-state measurements. As defined, a reading expressed in *"dbm"* at once indicates the power level of a steady, single-frequency signal where the number of *"dbm"* is equal to the number of decibels above or below a reference power of 1 milliwatt.

(c) DBM vs. VU. It is to be noted that a "VU" reading can be made only on a standard volume indicator whereas *sine-wave* power measured with the standard volume indicator or with any other suitable a.c. instrument can be expressed in *"dbm"*.[4]

DBM is a unit of finite power whereas "VU" is a measure of volume level and, as already discussed, *has no connotation of finite power level.* Thus no direct relationship between *"dbm"* and "VU" can be established.

From a practical standpoint, however, some relationship is desirable between the "VU" level used for program transmisson peaks and the *"dbm"* level used for system measurements. In practice it has been found that with typical program material of a given crest amplitude, the standard volume indicator reaches an indication 8 to 14 db *below* that reached with a steady tone of the same crest amplitude. To nominally take into account this 8 to 14 db difference in response, the established practice is that performance requirements must be met at a single-frequency test-tone level that is at least 10 db *higher* than the normal program peaking level (for example, in a system that is to transmit program material at +8 VU, all single-frequency measurements would be made at +18 *dbm* test-tone level). This procedure reasonably insures that system performance is within standards under normal operating conditions.

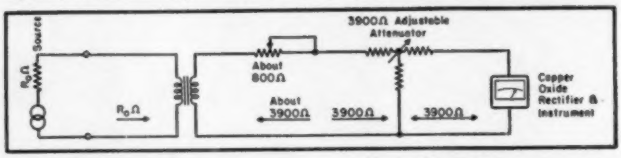


Fig. 6. Volume indicator circuit having low input impedance which terminates source and also provides increased volume indicator sensitivity.

Reading the Volume Indicator

Since program material is of a rapidly varying nature, a reading of a volume indicator cannot be obtained instantly. Rather, the gyrations of the needle must be watched for an appreciable period of time, the length of time depending upon the program material. For speech a 5 to 10 second period of observation may be sufficient whereas for symphonic music 1 to 2 minutes may be necessary. During this time the adjustable attenuator, which is a part of the volume indicator, is adjusted so that the extreme deflectons of the instrument needle just reaches the reference point; i.e., a scale reading of zero on the VU scale or 100 on the percent voltage scale (see *Figs.* 2 and 3). The volume level is then given by *the designations numbered on the attenuator.* If, because of the coarseness of the adjustments provided or for other reasons the deflections cannot be brought exactly to the 0 VU or 100 per cent mark, the reading obtained from the setting of the attenuator may, if desired, be corrected by adding the departure from 0 shown on the VU scale of the instrument. In the interests of accuracy the steps on the adjustable attenuator should not exceed 2 db. so that the departure from the reference point never need exceed this amount. Particular attention is called to the fact that, unlike almost any other electrical indicating instrument, *the volume indicator reading is determined primarily from the setting of the associated range switch* and, in effect, only a secondary correction is obtained by observing the deviation of the needle from exact coincidence with the reference point on the scale.

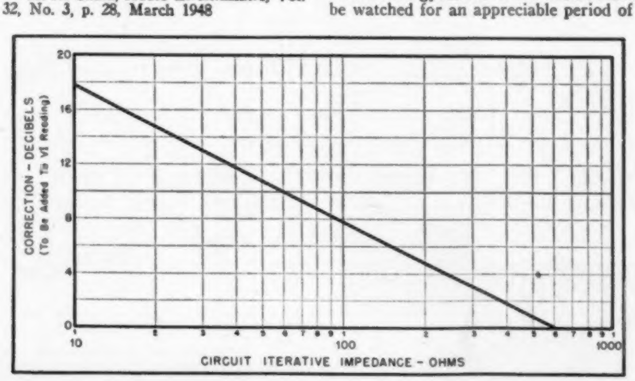


Fig. 5. Volume indicator correction factors (to be added to volume indicator reading) for use when instrument is bridged across circuits having iterative impedances other than 600 ohms.

Features of the Standard Volume Indicator

The volume indicator that has been described has the statute of an American Standard.[5] In the many years since it was first placed into service there have been no changes, whatsoever, in either the fundamental requirements or the specific features of the instrument that was developed to meet the basic needs. Because of the importance and the widespread use of the instrument some of the detailed characteristics that are of concern to the design engineer are presented below.

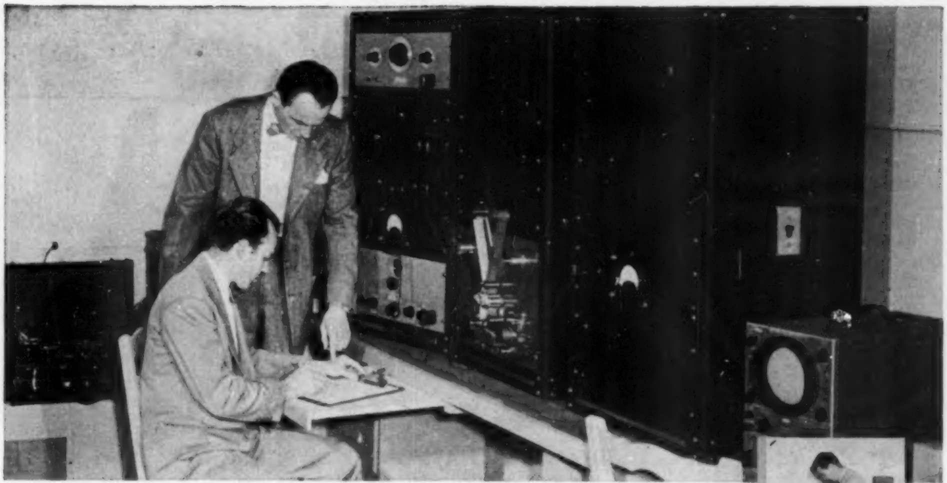
(a) *Response vs. Frequency Characteristic.* The sensitivity of the volume indicator instrument shall not depart from that at 1000 cps by more than 0.2 db between 35 and 10,000 cps nor more than 0.5 db between 25 and 16,000 cps.

(b) *Input Impedance.* The impedance of the volume indicator arranged for bridging across a line is about 7500

[*Continued on page 48*]

[4] H. A. Chinn, AUDIO ENGINEERING, Vol. 32, No. 3, p. 28, March 1948

[5] Volume measurements of electrical speech and program waves, American Standards Association C16.5–1942



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EDWARD TATNALL CANBY*

The RJ Speaker

A COUPLE OF ISSUES back I made some cryptic remarks about a new speaker enclosure system I had seen and heard, small enough with a 15 in. speaker in it for "your wife to sit on with a tight skirt." That somewhat risque analogy was used deliberately (after I had discarded plenty of others!) to indicate that it was small—but not how small. The basic idea behind this new speaker system is so simple that—at this writing still—I simply cannot believe it. Either it's true and we have here something quite revolutionary in its practical significance; or else the whole thing is a large bubble of hot air. I'm willing to take a risk, anyhow; but until this appears, it will not have been fair to the designers of the equipment to give the "secret" away, since protection was not yet secure, and hence in my first mention I was as vague as could be.

Is Bigness Necessary?

The trend in the last year or so in speaker enclosures as we all know has been towards the monstrous. "Bigger and Better" is a rather accurate description of many of the new horn-assisted systems. Yet in most other phases of electronics and audio, the trend has been mercifully towards smaller and smaller. The basic elements of a phonograph system have shrunk astonishingly since before the war—styli, pickups, arms, motors, amplifiers and their tubes and capacitors, even speakers; for the potent-magneted PM speaker gives more music for less size than most pre-war electrodynamics. Records too. The decrease in size-per-minute of music is of course the biggest development of all. Which only serves to isolate the speaker enclosure as the glaring exception to the happy rule of the miniature.

And the worst part of it is that with a huge and heavy enclosure necessary for good sound in an audio system, the rest might just as well take up space too. Things as a whole, then, remain overly big partly because it just isn't worth fussing too much with miniature problems. And so we have two general alternatives these days in the larger audio field: put out bulky equipment and get the best in sound; or put out portable, modestly proportioned stuff—and sacrifice heavily in the quality. Both lines of thought are being followed assiduously. What we need, however, is to have this particular cake and eat it. If we could have a small outfit that at the same time gave top quality, include the all-essential good bass response, then we would have a bonanza-producer. The answer to a hundred thousand dealers' prayers. And a million record owner's equally insistent dreams. It looks to me as though *maybe* those dreams and prayers could be answered, by the new speaker enclosure which I shall call, for lack of an official name, "RJ", after Frank Robbins and William Joseph (Sales Engineer, Milo Electric) the team who have worked it out.

RJ—for the Tight Skirt

Perhaps you will see why I have been enthusing over RJ these several months when I give you the bare essentials. Take a standard high quality two-way speaker system, 15-in. woofer plus tweeter. Mount the 15 and the tweeter both together into an RJ enclosure that is *roughly 18 inches square.* Measure the output of the system and discover for yourself that you are hearing sound with a cleaner, flatter "curve," with far better transients than the average reflex box, with bass response flat down to below the best in standard reflex arrangements, there is no peak whatsoever. And all this at a sacrifice of about 3 db in output efficiency, since only the frontal output of the speaker is used.

Look at it differently. Here, coming out of this 18-in. square box, is sound that can match or surpass the sound from the largest and heaviest of bulky systems in a number of ways. Perhaps, from the professional's viewpoint, it will not rate as *the* finest system in all respects. But enough that it rates among the better systems—and takes up such an incredibly small space! What more can you ask?

Still another angle. Take a quality 8-in. speaker and tie it to a 6-in. as a tweeter. Mount these two in an RJ box *9 inches square.* (I was going to say a hat box—but that's too big; call it a pill box.) You will thereupon achieve flat bass response down in the 70's or so, equivalent to response of many a far larger, full-sized cabinet and surely better than any of the usual commercial open-backed arrangements, "consoles," as they are so euphemistically called. How about a "console" that will sit happily on a dinner plate? This one I've heard, in a sort of pilot hand-made arrangement and am hoping to have one built as soon as practicable. Hearing's believing, with me.

Exact figures are not important in this sort of discussion—my intention is to give you the general idea of this—in case it proves to be as good as it looks and sounds. Size for size all the way up and down, the RJ type of cabinet enclosure will give you excellent bass response and smooth over-all response equal to enclosures that simply dwarf it. If this principle works, then we *can* have our cake and eat it.

RJ's Innards

Engineering not being my profession, I make no pretense of giving a proper technical description of the RJ principle. I can give you plenty to go on with yourself, from this point—the device now being adequately protected. Back of it is the Helmholtz resonator. To be more exact, the RJ Enclosure is a modified form of Helmholtz resonator, according to the Helmholtz principle of bass response. The back wave of the woofer is not used—hence both the 3 db loss in efficiency and the smooth response, minus the interference peaks and valleys of systems using combined front and back wave projection, most commonly found in the bass reflex. Both sides of the cone are loaded—not just the back, as in most enclosures.

Work on both sides of the cone, back and front. Load up the back side, as in the conventional fully-enclosed baffle, damping out the back wave. But load up the front too, and the pressure is equalized. With the front also loaded, the rise in resonant frequency that normally occurs with smaller and smaller enclosed air space behind a speaker is eliminated. Thus one can use a far smaller air volume—and a small space. No big box full of air. In fact, RJ has almost no rear space at all, to speak of, and the cubic measurement is no longer a crucial factor in the response. It figures instead in the tuning.

How to load up the front, yet let through

[*Continued on page 30*]

* *279 W. 4th St., New York 14, N. Y.*

RECORD REVUE

[*from page 28*]

the sound? That of course is the whole simple, ingenious trick. In the design I've seen, the woofer is mounted facing down. It speaks into a carefully designed rectangular duct. (It took months of theoretical work, after the system was actually working, to derive the necessary all-over formulas to fit every possible situation.) As I get it, the duct measurements are calculated to tune with the cavity behind the speaker. Sound issues from a slot extending across the base of the enclosure—there **is**, I gather, some horn loading on the way from the duct to the outside slot, but it is not of importance in increasing efficiency.

And thereby hangs a short tale. The slot principle is a very ancient one in musical instruments, though remarkably seldom used in the audio field. (Some of the recent very high range tweeters use it.)

Slots

The finest way to achieve real sound distribution through a wide angle is to use a slot. Sound issuing from a horizontal slot curves sharply upward and downward in a sort of fan-shaped "spray". The most telling example is the organ pipe—which achieves a fabulously good distribution of sound from a relatively tiny slot, even in the largest and most majestic bass pipes hardly thicker than your thumb and the length of your hand. Apply that to the RJ (which could, theoretically, use an opening of any shape, as long as the area were correctly calculated) and the bass, coming from what seems to be a very thin and unimpressive slot, fills a room to perfection, distributing itself most effectively. Point-source is virtually eliminated.

The same idea may be used at the tweeter end, though the RJ principle is applied only to the woofer. I have seen a six-inch speaker used as an inexpensive tweeter which was thus mounted behind a solid piece of wood with no more than a slot across it. The sound distribution was excellent. In some projected models of the RJ enclosure the tweeter sound will also issue from a slot, possibly mounted in the "roof," facing upwards, or alternatively at the upper section of the front face, the bass slot occupying the bottom segment.

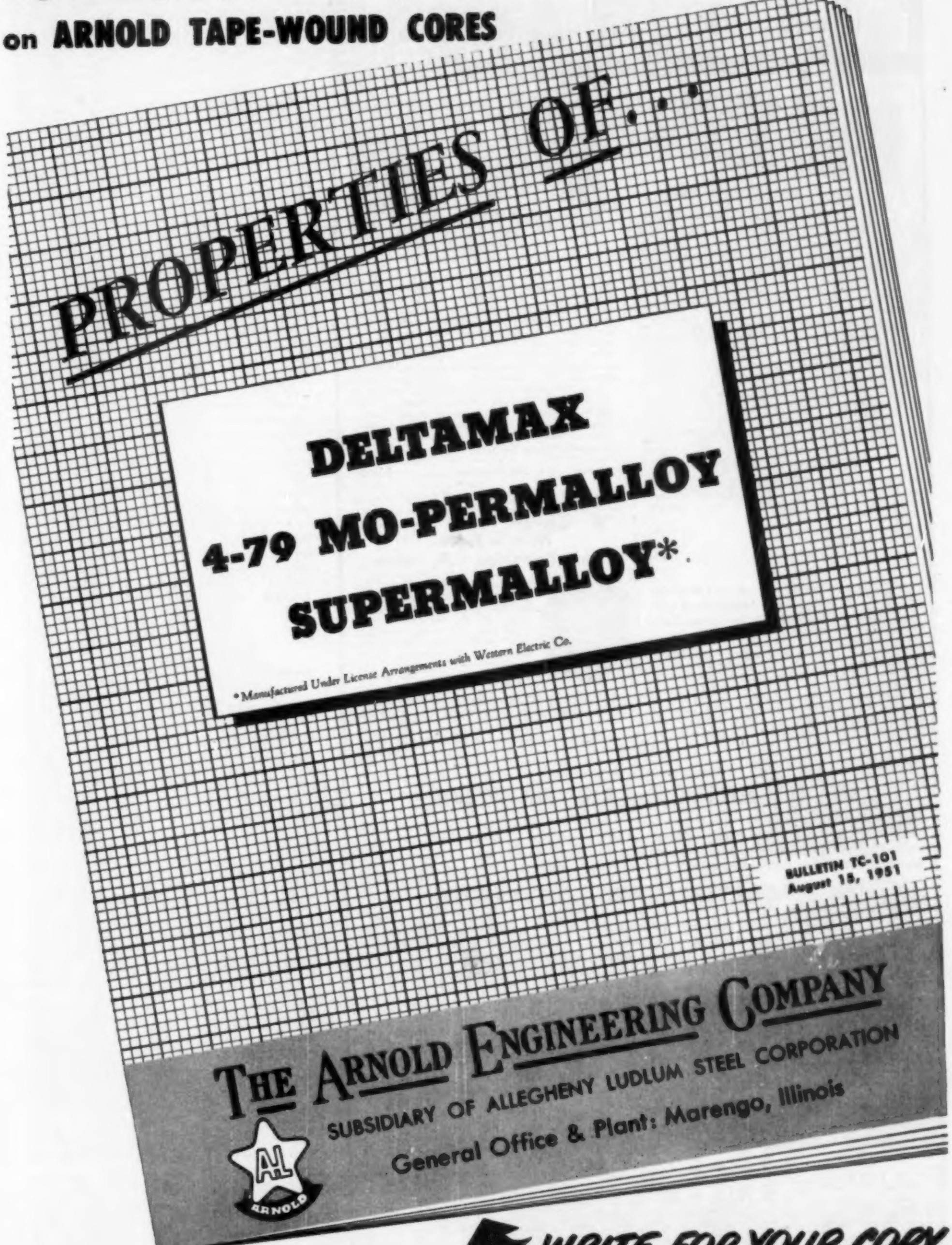
Enough said about RJ's insides—most engineers will be able to take over from here and do their own opining, pro or con. There *must* be something wrong or it would have been done before. And yet—is there? I mean fundamentally wrong, wrong enough to outbalance the absolutely inestimable advantage of enormously diminished enclosure size? That is the question. I grant that for the professional perhaps this matter of size is not of top importance. But think of the larger "market" for the entire range of audio equipment, from the hi-fi record collector and engineer right on down to the buyer of a miniature portable radio. Size is a vital thing for all of these people. Bulky equipment is tolerated and even welcomed by a good many, because it has been an unalterable rule that quality requires bulk. And if it is quality or nothing, then bulk is OK. But once you have so much as hinted that the eternal rule has been dented, even by ever so little—and anything may happen!

Applications

Let me for a moment take it for granted that the RJ enclosure is as good as it seems

Engineering Data

on ARNOLD TAPE-WOUND CORES



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to be, that it will rank technically well up with others, that it can be exploited. In other words, let me assume (as I think is the case) that here we have a very large saving in size for any attainable degree of quality. An improvement from any size-versus-quality basis.

Take the hi-fi area. The bigger RJ—the biggest being the small 18-in. cube or its approximate—will take any type of single woofer speaker. Fifteen-inch speakers give more efficiency and it may well be needed; but 12-inch speakers give remarkably good performance too. The tweeter section is adaptable as per convenience; it may be built in wherever ingenuity or convenience dictates. Needing no air space of its own, the usual tweeter unit can be included within the cube or near-cube framework of the woofer enclosure, for good looks and good centering of sound source. At present, the RJ proponents are concentrating on this aspect of the RJ development—for the best possible quality with quality components.

(Note one disadvantage of sorts: the RJ enclosure will not take a coaxial speaker system, since the tweeter would then be inside the box. Highs would be attenuated.)

In the hi-fi area, the RJ enclosure may prove of tremendous importance to those buyers of high-quality equipment who have sumptuous but none-too-big living rooms and tend, even against engineering advice, to order those dreadful combination "armchair console" arrangements which sacrifice so much in acoustical response in favor of smaller size. The RJ enclosure can be used as a chair or a coffee table or a chairside stool; it beats any chairside conventional arrangement all hollow—and gives far superior quality. With such a speaker the objection to a separate box is largely nullified. Amplifier and controls—possibly remote—could then be stowed away with the greatest of ease. I see extraordinary possibilities here, in the ultra-custom department.

Medium-fi

But, though the RJ partners have been too busy to extend their experiments yet, I have a strong feeling that the RJ principle may be even more useful in the less expensive areas. Take the medium-fi area—the cheaper separate-unit arrangements and the huge number of "console type" manufactured phonographs that people insist on buying. RJ can't improve their amplifiers and their distortion in the high end. But—build an RJ enclosure into any old console and you'll improve the bass response tremendously. I can't see anything that would make this sort of enclosure prohibitively expensive. I can easily envision a whole line of machines such as Philco, RCA, Zenith or the like which, featuring "Magic Bass" or something equally evasive, might actually provide a kind of true bass response such as has never before been heard in a standard console.

But far more important than the console radio-phonograph is the table model. As every engineer will have to admit, grudgingly enough, 99 per cent of the people want, first of all, a table model—either a sit-up or a true portable. They want it so much that they will pay outrageous sums for phonographs with 5-inch speakers and a speaker enclosure several inches long.

RJ has not actually been tested yet to see what sort of improvement can be had in the way of better bass with the small speakers and tiny space in the millions and millions of such small portable machines—which are anything but low-priced. My hunch is that some extraordinary sounds might be caused to emit from those ordinarily bass-less horrors. Heaven only knows just where the

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bass ceases to exist on such systems—but if a bass "floor" of 200 cps could be stretched down to 100, results would be, relatively speaking, sensational. You may laugh, but keep in mind that the great majority of present record owners, many of them plenty cultured and knowledgeable, own just such machines.

I can also conceive of a simple RJ front-loading system, perhaps stamped out of plastic, that might well revolutionize the tiny plastic radio sold by the millions. But now I'm becoming astronomical!

New style custom sets?

I suppose my chief asset is my unbridled imagination—set a'rolling by prospective new devices such as this. Can't quite stop yet. My fondest hope, since I've been following RJ's progress these last few months, has been that out of this might come what I have always wanted to see, a really good medium-priced type of semi-custom outfit that would fall in that large gap between real "hi-fi" equipment and commercial manufactured stuff. Something that would take advantage of the price differential, that would also take advantage of every bit of engineering ingenuity, to achieve a really useful, small-sized, inexpensive, portable, flexible phonograph system for the great majority of ardent record collectors who can't manage present hi-fi either as to cost or as to bulk.

As an experiment in this direction I'm working now on having a little system set up, just for my own observation. It will have a special alumnium small-size Columbia LP player (hand made, for the beginning of LP) with an Astatic U-J crystal with the FL-33 arm and filter. A miniature-tube push-pull amplifier, transformerless, goes underneath, with flush volume and roll-off controls of solid aluminum; the whole unit is about 7 × 9 × 2½ in., with one end curved. This will feed into an RJ enclosure approximately 9-in. square, probably to contain two Permoflex speakers, or equivalent, an 8-in. "woofer" and a 6-in. "tweeter", working through a slot. The whole outfit will stand on a small typewriter table or can be carried under your arm. I expect—and hope—to get smooth bass down to as low as most bass-reflex cabinets for 12-in. speakers will give, if not better, and with better acoustical performance. Though not professionally hi-fi, the player-amplifier-speaker combination will be far in advance of most fairly expensive commercial large-size consoles.

I might add, to close, that RJ (so named by me) is here announced for the first time —and at my own risk, for the whole thing might be an utter frost, though I can hardly think so. It is not yet publicly on sale, but will probably be shown at the Audio Fair, as of present (August) plans. So far RJ has been applied to a Stephens 15-in. woofer, a University 12-in. 6200, a Western Electric 754A, and a Permoflex 8-in.-6-in. combination, with vaarious associated tweeters. The entire speculation herein included is my own, not in any way necessarily approved by RJ's two designers.

And so I cross my fingers.

RECORD LIST

Try these on your hi-fi outfit

(Note: The August issue carried listings without performer identification; the September issue, sacrificing some compactness, gave brief performer information, and this would seem to me to be a good compromise. Reader reaction has been decidedly favorable to these brief surveys and they will be continued. E. T. C.)

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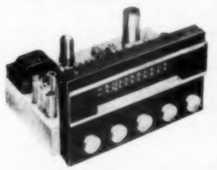

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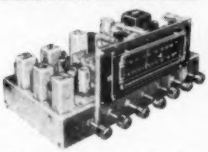

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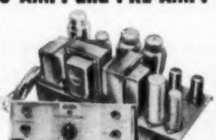

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Older music

[a] **Bach, Das Musikalische Opfer (Vuataz arr.).** soloists cond. Scherchen. Westminster WL 5070

[a] **Telemann, Trio in E Minor; Quartet in D Minor (Tafelmusik). Loeillet, Trio Sonata in B Minor.** Westminster WL 5076

Pergolesi, Concertino in F Mi. Respighi, Ancient Airs and Dances (Suite #3). Stuttgart Ch. Orch., Munchinger. London LLP 312

[3] **J. Haydn, Divertimento in C** (Winds and Strings); [a] **Four Military Marches. M. Haydn, Divertimento in C** (Strings). **Boccherini, Flute Quintet in D Flat.** London Baroque Ensemble, etc. Westminster WL 5080

"Romantic"

[1] **Beethoven, Trio in E Flat, Op. 3.** Pasquier Trio. Allegro ALG 3023

Brahms, Violin Sonata #1 ("Rain"). Stern-Zakin. Columbia ML 2193

[2] **Brahms, String Quartet #1, Op. 51, #1.** Budapest. Columbia ML 2191

Brahms, String Quartet #1, Op. 51, #1. Amadeus. Westminster WL 5084

Sibelius, String Quartet ("Voces Intimae"). Griller. London LLP 304

[a] **Beethoven, Violin Sonata in C Mi., Op. 30, #2.** Schneiderhan, H. Berg. Remington 149-35

Beethoven, Violin Sonata in C Mi., Op. 30, #2. Rostal, Osborn. London LLP 162

[a] **Beethoven, Variations on themes by Handel, Mozart.** J. Graudan, pf., N. Graudan, cello. Vox VL 6150

[4] **Beethoven, Trombone Sonata, Op. 17; Three Equali.** Shumann Brass Choir. Renaissance X 31

Matyegka-Schubert, Quartet for Flute, Guitar, Viola, Cello. Period SPLP 518

[b] **Debussy, Sonata #3.** Heifetz, violin; Bay piano. RCA 45: WDM 1515 (2)

Johann Strauss, J. Lanner: Waltzes. Alexander Schneider String Ensemble (Quintet). Columbia ML 2179

[1] **Beethoven, String Quartets, Op. 127, 130.** Pascal Quartet. Concert Hall CHS 1209, 1210

Modern

[c] **Milhaud, Madrigal, Pastorale. Berezowsky, Wind Quintet Suite, Op. 11.** Fine, Wind Partita. New Art Wind Quintet. Classic CE 1003

[2] **Sessions, Violin Sonata #2. Ives, Violin Sonata #2.** Patricia Travers, Otto Herz, pf. Columbia ML 2169

[a] **Martinu, Three Madrigals for Violin & Viola. Mozart, Duo #2.** J. Fuchs, vl., L. Fuchs, vla. Decca DL 8510

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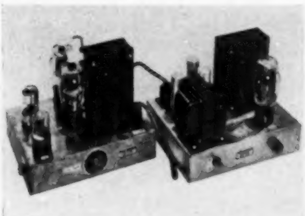
[1] Nice microphoning; some distortion in LP.
[2] Close-to, steely miking, in large space.
[3] Marches have excellent drums and snares.
[b] Bass is thin.
[c] Close, rather dead hi-fi recording.
[a] Some surface hiss.
[4] Dull music, but top trombone recording.

NEW PRODUCTS

• **Williamson-Amplifier Components.** Availability of low-cost transformers and choke for the Williamson amplifier circuit has been announced by Standard Transformer Corporation, 3580 Elston Ave., Chicago 18, Ill. Type designations are output transformer A-8054, power transformer

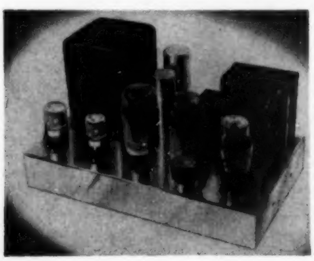


PC-8412, and filter choke C-1411. Laboratory tests of an amplifier built from the new Stancor components showed frequency response virtually flat at 8 watts output. Intermodulation measured 3 per cent. Harmonic distortion was negligible. Stancor will supply on request Bulletin No. 382, which describes construction of the Williamson amplifier, and includes chassis drawing, schematic, and complete parts list.

• **Crystal Cartridge.** Low cost and high output are combined in the new Astatic Model L-12 crystal for standard 78-rpm records. Output is rated at approximately 4.0 volts at 1000 cps on the Audiotone 78-1 test record. The pickup is designed to

operate with a needle pressure of one ounce and has a total weight of 18 grams. Crystal element is coated against moisture and housing is stamped steel. The unit is supplied without stylus and has a universal chuck for use with standard type needles. Manufactured by The Astatic Corporation, Conneaut, Ohio.

• **High-Quality Amplifier.** Remarkable characteristics are claimed for the new Craftsmen 500 audio amplifier, an all-triode unit based on the well-known Williamson circuit. It incorporates an output transformer of exceptional quality, and 20 db of inverse feedback around the entire amplifier. Characteristics supplied by

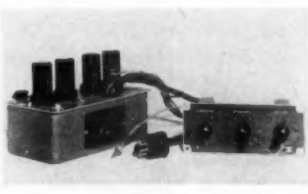


the manufacturer are: Total harmonic distortion, less than 0.1 per cent at mid-frequency; Intermodulation, less than 0.5 per cent at 10 watts; Frequency response, ± 0.1 db, 20 to 20,000 cps; Power response, ± 1 db, 10 to 50,000 cps. Manufactured by The Radio Craftsmen, Inc., 4401 N. Ravenswood Ave., Chicago 40, Ill.

• **Portable P.A. System.** Audio quality considerably better than average for portable p.a. equipment is featured in the Newcomb Model H-1512R. Containing two 12-in. speakers and a 17-watt amplifier in

a split case, the system provides inputs for two microphones and a turntable, and includes individual bass and treble tone controls. The equipment is housed in a fabricoid-covered plywood case with metal fittings and kickproof speaker grills. Over all dimensions are 11⅛" × 20¼" × 21". Total weight is 44½ lbs. Manufactured by Newcomb Audio Products Co., 6824 Lexington Ave., Hollywood 38, Calif.

• **Noise-Suppressor-Preamplifier.** Flexibility and performance of many home music systems, both new and existing, can be improved extensively with the new Scott Model 112-B "Dynaural" preamplifier. Circuit features the original Scott dynamic noise suppressor, high gain for magnetic-type pickups, variable turnover control to compensate for various recording characteristics, adjustable record-distortion



filter, and input level adjustment. Usable frequency response is 20 to 20,000 cps. The unit can be attached to most basic amplifiers by means of three standard plug-in connections. Remote control panel is handsomely finished in etched bronze. Bulletin will be mailed on request to Hermon Hosmer Scott, Inc., 385 Putnam Ave., Cambridge 39, Mass.

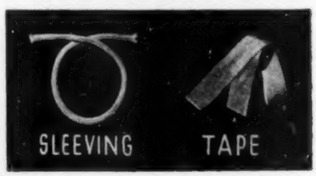
• **Fluid-Drive Pickup.** "Fluid Sound" is the trade mark applied to a unique new pickup cartridge now being marketed by the Lindberg Instrument Co., 830 Folger Ave., Berkeley 10, Calif. The device consists, essentially, of an actuating arm on which is mounted a conventional sapphire stylus, a plastic housing which contains three cells filled with an electrolytic, nontoxic, conducting fluid, and a rubber diaphragm. In operation, direct current flows through the three cells in series and is modulated by the stylus as it tracks the recording. The current modulations thus produced cause an output voltage to appear at the center cell electrodes, which is fed in conventional manner to an audio amplifier. Stylus-record contact is used only to modulate the externally supplied d.c. voltage as it flows through the fluid. It is stated by the manufacturer that the

Fluid Sound pickup reproduces fundamentals as low as 20 cps. Upper frequency limit is quoted as being 10,000 cps. The cartridge requires no bass boost and no special compensation of the highs. Tracking pressure range is 3½ to 10 grams, depending on the tone arm used, and output is 0.8 volts. Priced extremely low.

• **Phono-Radio.** Tasteful cabinet design, compactness, and good audio quality are all inherent in the "Vermont", a new table model phono-radio recently announced by Audar, Inc., Pasadena 18, Calif. Traditional Early American in appearance, the cabinet

is made of solid birch with hand-rubbed maple finish. The 7-tube chassis features separate bass and treble controls, push-pull power output, and an 8-in. speaker. Chairside stands and record cabinets in matching finish are available as accessories.

• **High-Temperature Insulation.** Refrasil is a fibrous silica insulation which provides both thermal and electrical insulation at temperatures up to 1800° F. De-



veloped originally in batt form for use in jet aircraft, the material is now fabricated in both sleeve and tape for a wide range of electrical applications. Flexibility is not affected by continued exposure to high temperature which, together with light weight, minimum bulk, and ease of slip-on installation, makes the material ideally suited for wiring electronic equipment where both resistance to heat and high dielectric efficiency are required. Further information about Refrasil may be obtained from The H. L. Thompson Company, 1733 Cordova St., Los Angeles 7, Calif.

• **Magnetic Recording "Rubber."** A special Neoprene base, into which has been incorporated a uniform pigmentation of magnetic oxide, is a new recording material recently announced by The Brush Development Company, 3405 Perkins Ave., Cleveland 14, Ohio. Also included in the base material is a permanent lubricant

which virtually eliminates wear of both medium and the recording head with which it is used. Designed for use when stretched over a supporting drum, bands of the material can be supplied in various sizes and shapes to meet special requirements. Requests for information should be addressed to Division D-4.

• **Corner Speaker Baffle.** Designed for use with eight-inch speakers, the new Permoflux corner cabinet affords good audio performance with remarkably low space requirements. Sturdily constructed of four-layer plywood, the baffle is attractively finished in maroon leatherette. Dimensions are 14 in. wide, 24 in. high, and 9½ in. deep. Tests, according to the manufacturer, indicate that the effect of corner radiation is more pronounced, relatively speaking, with this compact enclosure than with cabinets considerably larger in size. Permoflux Corporation, 4902 W. Grand Ave., Chicago 39, Ill.

• **Self-Holding Test Prods.** The New Klipzon Type H heavy-duty test prods and leads are designed for clipping to conductors and are suitable for many applications in electronic power supplies, public utility systems, and in electrical manufacturing and testing. Self-holding points

are needle-sharp for piercing insulation and will maintain effective contact until removed. Flexible leads are equipped with spade terminals, are four feet long, and consist of 16 strands of No. 30 B & S gauge copper heavily insulated. Manufactured by United Technical Laboratories, Morristown, N. J.

Audio in England

The 1951 Picture

H. A. HARTLEY

THE 1951 NATIONAL RADIO EXHIBITION offers an appropriate time to discuss developments in this country, of which there have been mighty few since my last contribution. In fact the only direction in which there seems to have been any progress is in TV, and the feature of this year's show is the arrival of the 12-inch tube. Please do not think I am trying to be funny. You who are accustomed to really big tubes in television sets cannot understand how Britain has so completely lost her leadership in TV. I think it is only fair to say that British television on any sort of mass scale was the first in the world, but now, when we read of what you have done, we look on our present situation with dismay. This is no fault of the industry, but simply due to the fact that TV is run as a sort of erring offspring of sound broadcasting, and given no chance of showing that it is an entirely new art. And, of course, there is no competition. We have to take what is given us whether we like it or not, and as many of us don't like it we don't bother buying TV sets, and as we don't buy sets in sufficient numbers to make full scale research and design in the factories a paying proposition, our receivers are not so imaginative as yours.

Audio

In the old days before the war we used the phonograph as a stop-gap because of what were, in those days, very good transmissions of music. Now we endorse what Ross Snyder said in his article in the August issue of Æ "Non-professional high-fidelity enthusiasts, we find, are more interested in good record-playing equipment than in anything else. Radio is most often regarded as an accessory, to be used for incidental listening, but not as a primary source of serious musical entertainment." How true that is.

We find the B.B.C. goes to some trouble to broadcast good orchestral concerts; we find no one takes the trouble to see that the technical quality of those transmissions is acceptable to a musical listener. Some of these broadcasts are so bad that they have to be heard to be believed. I have listened to transmissions and adjusted the controls of a carefully calibrated tone-control amplifier to reach some sort of conclusion as to the frequency response actually broadcast. One twiddles the controls to find how far one can go without adding or subtracting quality or absence of quality, and I have found orchestral stuff broadcast with a response apparently about 15 db up at 100 cps and a complete cut-off at 2500. Much of the output has nothing above 5000 and the extreme possible limit at the present day is just about 8000. I have taken this up with the B.B.C. engineering staff several times, and most of the blame is laid to the land lines. These are admitted to be bad by Post Office engineers, although there is always talk that new lines are on the way.

The musical enthusiast therefore turns to records which have improved enormously since pre-war days, and the advent of LP has, of course, revolutionized phonograph technique. No real hi-fi listener would ever have a record changer, and LP has killed the bugbear of having to change the records manually. But LP has introduced a whole host of attendant troubles and a good deal of dissatisfaction has been aroused in this country about the indifferent results that have sometimes been obtained after spending considerable sums of money.

Letters

One of the things that pleases me so much is the ever increasing number of letters I get from Æ readers. I find these interesting, informative, and thoughtfully and sensibly written. They prove to me that the intellectual and technical level of the readership of this magazine is quite exceptionally high. I have had a good deal of information on the shortcomings of various makes of American LP's, and as it is not my job to comment on the American scene I can rejoin with some comments on British. Still we have only Decca, although it is now commonly rumoured that the E.M.I. outfit, realising at last that LP has come to stay, are coming in too. The story goes that since the Gramophone Co. (H.M.V.), having committed themselves by announcing that they would give six months' notice if they introduced LP, will not do so for the moment, but will introduce 45's *a la* Victor; but, since they (E.M.I.) will be forced to produce LP's, these will come out with Columbia labels. I cannot vouch for the accuracy of this gossip, for it is just rumour; all I can tell you is that our only LP's (apart from some pops by one of the small companies) are Decca.

I am told that, except for your Columbia's and those Capitol's which are not dubbed from Telefunken, the besetting sin of many American LP's is pre-emphasis of lows and highs in no sort of system at all. This may be, but the besetting sin of the early Decca's was, without a shadow of aural doubt, pre-emphasis of the highs. Decca never made any secret of the fact that their 78 ffrr had a rise of 3 db per octave at the top end of the characteristic, and this certainly made them sound as though they had more top than the usual run of discs. And ffrr sounded better on an ordinary radio-phonograph than did records which were recorded flat.

But it was another story altogether on a real high-fidelity outfit, for the top pre-emphasis did exactly what one would expect it to do—reproduce the harmonics out of proportion to the fundamental. And if you sought to counteract this pre-emphasis by a corresponding cut in the amplifier it did not appear to restore the harmonics to their pre-recorded value. The consequence was that all compound notes rich in harmonics, particularly the upper register of the violin, were harsh. In fact, they had harmonic distortion which we all try to eliminate in our reproducing system. What came to be considered "characteristic ffrr violin tone" always suggested a tissue-paper and comb effect. Not all Decca records did have this defect, which suggests that not all ffrr's had top pre-emphasis, but a large proportion of the earlier LP's sounded just like pre-emphasized 78's, ex-

cept that as there was more top on the LP's it sounded worse.

I started what was almost a public campaign about this, pointing out that it was the height of folly to damn this new development by making it sound beastly on high-fidelity equipment. I was on pretty sure ground too, because many of my American correspondents wrote to me pointing out this paper-splitting top on certain Decca LP's, and asking if I had any explanation. It wasn't wrong tone-correction in my equipment, for I was able to reproduce American Columbia to perfection. I don't know what eventually was done in the Decca recording menage, but it can be said that modern releases are of a consistently higher quality, and I am hopeful that they are adhering to the N.A.B. characteristic.

Against this background of "audio source," poor broadcasting, some good 78's and fairly consistently good Decca LP's, you will realize that we are not too well fed, as engineers, with the raw material of our trade. But against this background the statement that the 1951 Radio Show had practically no interest for the audio engineer will not appear surprising. Speaker and phono equipment demonstrations were non-existent except for the one show put on by Wright and Weaire who were demonstrating their tape-deck on a British-made Klipsch. This and the Simon tape-deck are considered as good as can be obtained in this country; they are two-speed, 3¾ and 7½ inches per second, and at the latter speed claim flat response from 50 to 10,000 cps. The "Wearite" demonstration was short and cautious, some speech, a violin, woodwind (carefully omitting the oboe), and with no brass, percussion, or full orchestra, in fact nothing that would give one the real low-down on what can be got out of tape. (By the way I should very much like to hear from any of you who can be bothered to write, what *can* be got out of tape, but as I shall be at the Audio Fair, perhaps I shall be able to hear for myself.)

The usual wide range of speakers by Rola, Goodman, W.B., and Grampian were in evidence, but all of these wholly admirable companies are mainly concerned with big-scale production of moderate priced speakers for set makers. Indeed one or two of them find the high-fidelity market such a nuisance from their angle that they very generously pass over their high-fidelity orders and enquiries to your humble correspondent (the British characteristic is ever to live and let live). Decca showed their corner indirect radiator, but no opportunity was found to hear it, if indeed such opportunity actually existed.

A small range of amplifiers of sound if unexciting design were on display, but again could not be heard working, and so I left the show with nothing learned except that the piped sound of every radio show there has ever been is worse than ever, though now so negligible that it hardly makes its presence felt.

In the outside world there is virtually nothing to report. The postwar epidemic of "high-fidelity" manufacturers of small dimensions has gradually faded out, for those who thought that all that is needed to click the high-grade market is to tack on the label "hi-fi" have not been able to make the grade, and the large manufacturers who turn out a luxurious-looking pantechnicon sell only to those who have money and no taste (and today more than ever are these two conditions poles apart). The real thing is left to the few firms who work on a personality basis, who really try to turn out something good and

who, it is sad to report, have a supreme contempt for all the others. This is not altogether without some reason, for I notice one firm that has professedly catered for the "music-conscious" market for many years offers, in the advertisement pages of one of our *technical* journals, a variable filter which steeply cuts "at any selected frequency between 4000 and 8000 cps" and then go on to say "specially valuable for use with new microgroove records". And I leave you to sort that one out for yourselves.

Examining the products of these various high-fidelity manufacturers I find there is absolutely nothing new at all. The twin-unit speakers in more or less elaborate cabinets continue as before, but with ever increasing prices, although I notice a slowly increasing consciousness on the part of the would-be customer that it seems impossible to achieve either complete merging of the sound of the two units, or completely smooth passage through the cross-over frequency. In Britain, of course, we have no speakers of the concentric tweeter-woofer type like your Altec's, Stephen's, Jensen's and University's. I do not know what these sound like, but I shall, as I have already told you. Meanwhile I continue to plough my lonely furrow of pinning my faith to a single highly specialized diaphragm, even if the metaphor ought to be blocked. The problem that now has to be solved by all us audio engineers is to find a way of getting good sound uniformly propagated throughout the auditorium, even though the "auditorium" is the usual somewhat restricted living room.

For the rest I promise you, at the editor's kind invitation, a complete list of the best British recordings of 1951, and all the British LP's. That list will appear very early in the new year.

FEEDBACK DESIGN

[*from page 12*]

loudspeaker connected is equal to 21.6 db feedback with the loudspeaker disconnected.

Thus it is evident that in the case of a pentode it would be decidedly advantageous to place part of the plate-load impedance in the cathode circuit to provide some 10 db of local feedback. The ordinary 16-ohm loudspeaker winding is sufficient to provide 6 db of feedback over a single-ended stage. A local feedback loop of this type should make it possible to use more feedback than the usual 10 or 15 db around a loop from the voice coil to a preceding stage, since changes in the load impedance will have a much smaller effect on this loop. With enough of the plate winding in the cathode circuit to provide 10 db of feedback, a pair of pentodes is likely to require less driving voltage and less input power, and to have less distortion and lower output impedance than triodes with the same power output.

Independent Control of Gain and Internal Impedance

It will be noted also from (B) of *Fig.* 1 that positive current feedback decreases the output impedance since it adds $-A_o a$ to Z_o. If in the case of the pentode enough positive current feedback were applied from the cathode of

the output tube to the cathode of the driver to increase the gain 20.8 db, measured with the load connected, then the output E_o would be the same whether the load were connected or disconnected and $Z_o - A_o\alpha = 0$. If in addition we apply negative voltage feedback so the shunt arm $(Z_o - A_o\alpha)/-A_o\beta$ comes into play and reduces the gain by 20.8 db, then we have reduced the output impedance to zero without changing the gain at all. The harmonic distortion also remains unchanged. By combining current and voltage feedback the internal impedance can be made any desired value—positive, negative, or zero; at the same time the gain can also be made any desired value.

Illustrative Phonograph Preamplifier Design

To illustrate the practical use of these circuits, suppose we wish to design a preamplifier stage that will equalize a magnetic phonograph pickup to the standard playback curve for Columbia LP records. Let us assume the pickup is flat on a velocity basis. The tube will be one high-mu triode section of a 12AX7 in the circuit of *Fig.* 4; and let us suppose that for reasons of economy the cathode bypass capacitor is omitted.

The frequency response curve we intend to create is that derived from the inverse of the Columbia preemphasis network[1] in *Fig.* 5. Its inverse with respect to an arbitrary resistance R_o is shown at (A) in *Fig.* 6 together with three equivalent circuits having the same response. *Figure* 7 shows the straight-line approximation to the playback response curve.

To achieve this response all the impedances in *Fig.* 4 will be made pure resistances except for Z_2. By using a large coupling capacitor, Z_L over the audible range can be considered to be made up of the plate resistor and the following-stage grid resistor in parallel. One can see from (D) of *Fig.* 3 that if there were a very large amount of feed-

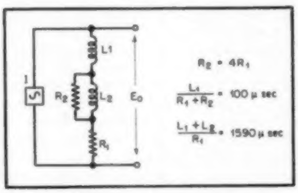


Fig. 5. Columbia LP pre-emphasis network.

back at all frequencies the gain would be simply Z_2/Z_1 and we could get the required response by making Z_2 the network of (A), *Fig.* 6. In this case we intend to use only about 6 db of voltage feedback at low frequencies and so the network will have to be modified. We shall see that the response obtained with a limited amount of feedback is the same as that obtained with infinite feedback when a resistance is shunted across Z_2. This effective shunt resistance may be

[1] "Columbia LP microgroove records," Audio Engineering, August 1948, p. 24.

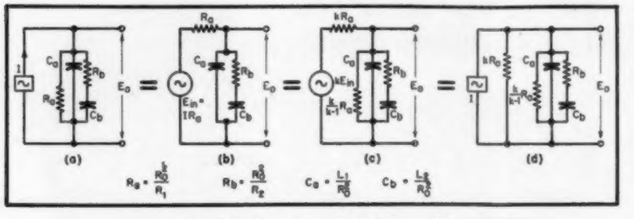


Fig. 6. Playback network for LP records.

included in the network as a part of R_a.

Our first task is to consider the amplifier stage with cathode degeneration alone and no plate-to-grid feedback. From tube data[2] we find that one section of a 12AX7 has a gain of 68 and is capable of putting out 79 volts peak with the following circuit constants: plate supply, 300 volts; bypassed cathode resistor, 3100 ohms; plate-load resistor, 0.22 meg; and following-stage grid resistor, 1.0 meg. From a guess at the operating point the curves indicate an amplification factor of 95. Combining this with a gain of 68, a Z_L of 180,300 ohms and $Z_K = 0$ in the circuit of (B), *Fig.* 2, we find that $R_P = 71{,}600$ ohms. When the cathode bypass capacitor is removed we find that we have a gain $A' = 31.1$ and an internal resistance Z_o' of 122,200 ohms.

[2] RCA Tube Handbook HB-3, Resistance-Coupled Amplifier Charts.

We have thus reduced the triode with 6.8 db of cathode current degeneration to a generator of voltage $-31.1\ E_{in}$ with an internal impedance Z_o' as in (C) of *Fig.* 2. Had we made a poor guess at the mu of the tube we would still have arrived at the correct answer for gain with feedback, although the internal impedance would have been somewhat in error.

Next we proceed to reduce the complete stage, which can now be drawn as at (A), *Fig.* 3, to its approximate equivalent, (E). Comparing (E) of *Fig.* 3 and (D) of *Fig.* 6, we see that they can have the same frequency response if Z_1 is a resistor and Z_2 is a four-element resistance-capacitance network. If for the moment we disregard the factor $[Z_o/A_1Z_1]$ (E) of *Fig.* 3, which simply determines the impedance level of the entire circuit without affecting the open-circuit response, we see that the gain-versus-frequency is directly proportional to the combined impedance of Z_2 in parallel with the resistor $(A_1+1)Z_1$.

In short, returning to (A) of *Fig.* 3, we find that the gain-versus-frequency is simply Z_2'/Z_1 where Z_2' consists of Z_2 in parallel with a resistance $(A_1+1)Z_1$. This rule for computing the response also applies when Z_1 is a complex network. It holds whenever Z_1+Z_2 is so large that it does not load the output circuit appreciably or cause any appreciable amount of signal to feed directly through from input to output.

To determine the loading and direct feed-through we examine the response curve, *Fig.* 7, and find the minimum value that Z_1+Z_2 can reach within the audible range. Since we have decided that the gain reduction at low frequencies is to be 6 db, this means that at 15,900 cps the gain will be down 34 db more or only 0.31. At this frequency and above, Z_2 has become so small that the

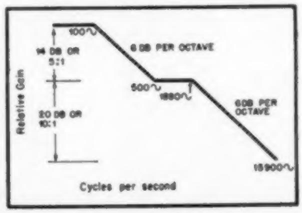


Fig. 7. Asymptotes to LP playback curve.

loading and direct feed-through are determined almost entirely by Z_1 and the internal impedance with feedback. According to (C) of *Fig.* 3, at high frequencies where Z_2 approaches a short circuit, the internal impedance approaches $Z_0/(A_1+1)$ or 3780 ohms. If we choose Z_1 about 100 times this value, then the loading and direct feed-through will cause an error of less than 0.1 db up to 20,000 cps.

This low value of internal impedance at high frequencies makes the amplifier quite immune to the capacitance effects of adding a following stage or an output cable.

The effective parallel resistance $(A_1+1)Z_1$ across Z_2 is now identified with the resistance KR_a of (D), *Fig.* 6. It is convenient to set this value at 12 megohms, making Z_1 equal 374,000 ohms. Since we want to have 6.02 db of gain reduction at extreme low frequencies, amounting to 5.80 db feedback and 0.22 db loss due to input voltage division between Z_1 and (Z_2+Z_0), Z_2' must be just half its no-feedback value, or 6 megohms. This means that Z_2, which approaches the resistance $KR_a/(K-1)$ at low frequencies, must be 12 megohms. Putting together the relationships $KR_a = 12$ megohms and $KR_a/(K-1) =$ 12 megohms determines the value of R_a as 6 megohms. The remainder of the network can be found from the relationships in *Fig.* 5 and (A) of *Fig.* 6.

Figure 8 shows the completed circuit. In order to maintain the best possible low-frequency response, the coupling capacitor has been included in the feedback path. It was chosen for 0.1 db loss at 20 cps without feedback. Also the 80 µµf grid-to-plate capacitor has been made 3.3 µµf smaller than calculated to allow for tube and wiring capacitances. Such a preamplifier would be suitable for use with a Pickering cartridge which would provide the d.c. grid return to ground. To maintain the flat velocity response required at the input terminals of the preamplifier, this particular pickup should have a 27,000 ohm resistor connected across it. Other resistor values are required for different types of magnetic cartridges.

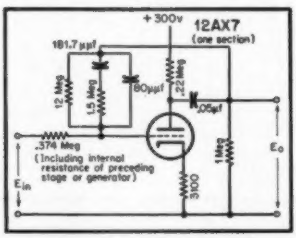


Fig. 8. Complete phonograph amplifier.

Extension to Multistage Amplifiers

The use of equivalent circuits stemming from (B), *Fig.* 1, is not limited to the cases illustrated where the only frequency discrimination occurs in the external feedback path. Ordinary multistage feedback amplifiers can be treated similarly. In general, the generator voltage A_oE_{in} is a function of frequency and so it becomes necessary to add the response curve of the network in db to the response curve of the amplifier without feedback A_o. When the total phase shift in the negative feedback lops exceeds 90 deg., at least one of the elements of the network will be a negative resistance.

New Hudson Consultant

One of the more remarkable figures in the audio field, Robert W. Gunderson, has been retained as consultant by the Hudson Radio & Television Corp., New York, to assist customers in solving technical problems.

Although totally sightless since birth, Gunderson, who is 32 years old, has achieved national prominence as an engineer, and because of his efforts to assist others who are similarly afflicted.

He is radio instructor at the New York Institute for Education of the Blind, from which he himself graduated in 1937, and has prepared hundreds of students for employment in industry, also many for ham licenses.

While Gunderson takes great pride in his own station W2JIO, his pet project is the Braille Technical Press, a radio and electronics guide for the blind which he publishes monthly at his own expense.

SQUARE WAVE TESTING

[*from page 15*]

As the test frequency is raised, the picture obtained on the 'scope gradually changes from a square to an approximate sine wave. This is because the test frequency is approaching the amplifier cut-off point and its harmonics are greatly attenuated. If the amplifier has a sharp cut-off, such as might be experienced with a low-pass filter, the wave at some frequency may appear double humped because of the presence, primarily, of the fundamental and third harmonic only, the fifth and higher harmonics being attenuated to the point where they have little if any effect. Thus a rough measure of the sharpness of cut-off may be obtained.

In making these tests, the low-frequency square wave must be sufficiently low that the high-frequency effects are not noticeable, and vice versa. In a narrow-band amplifier this may not be possible, but it is doubtful if anyone will want to make these tests on a narrow-band amplifier anyway.

Conclusions

The method given here makes possible the easy and rapid determination of the practical response limits of an amplifier. Also, if a good reproduction of the original square wave is obtained, these figures show that the amplifier response is good down to approximately one-tenth the test frequency. It can also be shown that the response under such conditions is also good up to about ten times the test frequency.

REFERENCES

1. Louis E. Garner, "Wide frequency range square-wave clipper" *Radio & Television News*, March 1950, p. 36
2. Gilbert Swift, "Amplifier testing by means of square waves" *Communications*, Feb. 1939
3. A. V. Bedford, "Transient response of multistage video-frequency amplifiers" *Proc. I.R.E.*, April 1939
4. L. B. Arguimbau, "Network testing with square waves" *General Radio Experimenter*, Dec. 1939
5. L. B. Arguimbau, "Transient response of a broadcast system" *General Radio Experimenter*, April 1940
6. Philip M. Seal, "Square wave analysis of compensated amplifiers" *Proc. I.R.E.*, Jan. 1949, p. 48

RECORD PROCESSING

[*from page 23*]

conductive, but which prevents permanent adhesion of the metal. The master thus treated is now pre-plated with copper or nickel, back plated and separated between the copper-nickel or nickel-nickel interface. Again to get a stamper from a mother the mother process is repeated as many times as necessary, starting with the mother and yielding

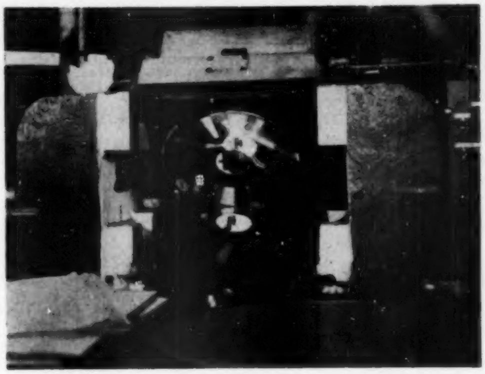


Fig. 9. Finished transcription being removed from one of the molding presses.

stampers. The stampers are finished by the chrome plating process outlined above.

After the stampers are completed they are sent to the press room where they are placed in the test press. A preheated, 240 to 260° F, square preform of the right weight of vinyl plastic, is placed on the master which has been heated to 300° F, and the press is closed. After about 5 seconds, pressure of 1700 to 1800 psi is applied for 40 seconds and cold water is circualted to cool the die. The press is opened after pressure is released and the test pressing removed. The three steps involving the press are called *cycling*. After the disc is pressed, the excess material at the edge—flashing—is removed, and the disc is inspected and delivered to the customer. On his approval the stampers, *Fig. 9*, are run until the order is filled.

For the run, two masters are usually required and are placed facing each other in the press, the labels are placed with their faces against the stampers, the preform placed on the bottom one and the press cycled. Inspection for air bubbles, blisters, and proper filling of the grooves then precedes the packaging and shipping.

Some of the headaches of processing include the $1500 gold foil sheets, lasting only two months, used in each of the gold sputtering chambers. Fifty cents worth of gold is used in the making of each master. To have the gold reclaimed would require 15 tons of old masters if the reclamation were to pay for itself. Direct current is used for the plating, of course, and to obtain the high current required six motor generators with a total a.c. power consumption of 25 kw are needed. The plant must generate its own steam, and must provide a large quantity of distilled water.

To supply the highest quality pressings the plant also manufactures wax masters for use by its pressing customers. This is the only plant in the country handling wax masters commercially.

High-quality vinyl pressings demand close control of the chemical processes and mechanical operations. No polishing or other degradation of the master is permitted. The process as outlined is the one now used to produce frequency test records which cover the audio range from 50 to 20,000 cps.

The author wishes to acknowledge the cooperation of K. R. Smith and the staff of the K. R. Smith Division of the Allied Record Mfg. Co. in the preparation of material for this article.

ERRATUM

The schematic of a vacuum-tube phase shifter described in the *Audio Patents* section of the August issue of Æ—Fig. 4, Page 49—shows the plate resistor R_2 shorted and the output capacitor connected to B+.

It is to be hoped that the patent on the device is more valid than was Æ's diagram illustrating its performance.

Sorry.

AUDIO VOLUME MEASUREMENT

[*from page 26*]

ohms when measured with a sinusoidal voltage sufficient to deflect the pointer to the 0 VU or the 100 per cent scale marking. Of this impedance, 3900 ohms is in the meter and about 3600 ohms must be supplied externally to the meter, this value of series resistance being required in order to meet the above dynamic characteristics.

(c) *Sensitivity.* The application of a 1000-cps potential of 1.228 volts r.m.s. (4 db above 1 milliwatt in 600 ohms) to the instrument in series with the proper external resistance (3600 ohms) causes a deflection to the 0 VU or 100 point on the scale. The instrument, therefore, has only sufficient sensitivity at its normal reference point (0 vu or 100) to indicate a volume level of +4 VU. It has not been found possible to design more sensitive instruments while meeting other requirements.

There should be no confusion because the instrument deflects to a scale marking of 0 VU when a level of +4 VU is applied to it. The 0 point on the VU scale is merely an arbitrary point at which it is intended nominally to read the instrument, and the rest of the VU scale represents deviations from the 0 point. The volume level is read, not from the scale, but from the indications on the associated sensitivity control when the latter is set so as to give a scale deflection of zero (as detailed in a foregoing section).

(d) *Overload Capacity.* The instrument is capable of withstanding, without injury or effect on calibration, peaks of 10 times the voltage equivalent to a deflection to the 0 vu or 100 scale point for 0.5 second and a continuous overload of 5 times the same voltage.

(e) *Presence of Magnetic Material.* It should be cautioned that the presence of magnetic material near the movement of the instrument may affect its calibration and dynamic characteristics. This is because, to obtain the desired sensitivity and dynamic characteristics, it has been necessary to employ more powerful magnets than usually required for such instruments, and any diversion of flux to nearby magnetic objects effectively weakens the useful magnetic field beyond the point where these characteristics can be met. The instruments should not, therefore, be mounted on steel panels. (The effect is only slight, however, if they are mounted on 1/16-in. steel panels with the mounting hole cut away as far as possible without extending beyond the face of the meter case.)

In the instruments as now available, the deviation of the sensitivity with temperature is less than 0.1 db for temperatures between 50° F. and 120° F., and is less than 0.5 db for temperatures as low as 32° F.

The instrument by itself does not con-

stitute a complete volume indicator but must have certain simple circuits associated with it. The basic form which this circuit takes is illustrated in *Fig.* 4. This is a high-impedance (7500-ohm) arrangement intended for bridging across low impedance lines. As noted above, about 3600 ohms of series resistance has been removed from the instrument and must be supplied externally in order to provide a point where the impedance is the same in both direction, for the insertion of an adjustable attenuator. A portion of the series resistance is made adjustable as shown by the slide wire in the diagram. This is for the purpose of facilitating accurate adjustment of the sensitivity to compensate for small differences between instruments and any slight changes which may occur with time.

The maximum sensitivity possible with this, the simplest circuit, is +4 vu for indications at the 0 vu or 100 per cent mark when placed across 600-ohm line. The maximum sensitivity occurs, of course, when the loss in the adjustable attenuator is zero. The upper limit to the range of measurement is limited only by the amount of loss introduced by the adjustable attenuator, its power handling capacity and that of the two series resistors.

The volume indicator of *Fig.* 4 can be bridged across circuits of other than 600 ohms, of course, but when this is done a correction factor must be applied in order to determine the true level. *Figure* 5 shows the magnitude of the correction factor. It is to be noted that the basic volume indicator circuit (*Fig.* 4) has an input impedance of 7500 ohms and should not be bridged across circuits of appreciably higher than about one-tenth of this impedance if undue loading of the circuit is to be avoided. On the other hand, when used across circuits of less than the normal 600 ohm value, the sensitivity of the instrument is reduced, as indicated by *Fig.* 5.

Figure 6 shows an arrangement in which, by adding a transformer, the sensitivity has been increased at the expense of decreasing the input impedance to a low value. The circuit is designed so that the impedance facing the instrument itself is the same as in the basic circuit (*Fig.* 4). Thus the correct dynamic characteristics are obtained. The input impedance, on the other hand, is low, hence the device cannot be bridged across a through line but must be used to terminate the circuit. In practice, approximately a 10 db increase in sensitivity may be obtained by this arrangement.

In high-fidelity audio systems the use of a 150-ohm circuit impedance is becoming common practice.[6] However, when the basic volume indicator circuit is used with 150-ohm circuits a loss in sensitivity of 6 db results. Therefore, on a 150-ohm circuit the instrument is ca-

[6] Monroe and Palmquist, *Proc. I.R.E.*, Vol. 36, No. 6, p. 786 (June 1948).

pable of reading levels only down to +10 vu. The loss in sensitivity in situations such as this can be avoided by utilizing a circuit similar to *Fig.* 6 except that the step-up ratio of the transformer is made only great enough to overcome its own losses and that which results from the existence of lower voltage (for a given volume level) on a circuit of lower impedance. In the particular instance cited a step-up ratio of slightly more than 1:2 would be necessary if the transformer were without losses and slightly greater than this in a practical case.

The input impedance of the volume indicator (7500 ohms in the basic circuit) will be reduced under these circumstances by a factor equal to the square of the turns ratio. This is not a serious disadvantage, however, since the impedance of the circuit being bridged has also been reduced by essentially this same factor. Therefore the ratio of the circuit impedance to the bridging impedance remains approximately the same. For the particular example cited, namely a 150-ohm circuit, practical volume indicator transformers, when terminated in a standard volume indicator, have input impedances of about 1700 ohms.

Transmission Level Practices

The volume levels that are used for the transmission of speech and program waves may be determined upon in a number of ways depending upon the communications service involved. For example, in a system employed for voice communication, where loss of naturalness of the speaker's voice is not a factor, the relative audio levels might be maintained as high as possible without loss of intelligence. Another criterion might be the transmission of voice and music at the same loudness. On this basis, using the standard volume indicator, voice would be peaked 2 or 3 db below music.[1] Still another possible basis for determining relative transmission level is the appearance of aural distortion caused by overloading of the particular facility involved. Determinations of this kind are usually made on an A-B test basis[1] and the results will depend to a large extent upon the shape of the overloading characteristic of the system involved. Transmission practices based upon this criterion ensure the maximum use of the facility concerned while avoiding detectable aural distortion. For this reason it has great appeal, from a purely technical standpoint, for high-fidelity broadcasting and sound recording applications. However, it does not take into consideration the listener's preferences.

Program transmission practices, where listening for pleasure is concerned, may well be determined on the basis of the average listener's wishes. A study[7] made with this criterion de-

[1] Chinn, Gannett and Morris; *Proc. I.R.E.*, Vol. 28, No. 1, p. 9, Jan. 1940.
[1] *Loc. cit.*, pg. 4.
[7] Chinn and Eisenberg, *Proc. I.R.E.*, Vol. 35, No. 12, p. 1547 (Dec. 1947).

veloped that on the average, listeners prefer to hear broadcast music and speech at about the same peak levels *as read on a standard volume indicator.* Furthermore, listeners like to hear broadcast music and speech at the same *relative* levels, regardless of the *absolute* sound level that is individually preferred.

The Columbia Broadcasting System is following this practice with considerable success. The measure of success in this instance being the almost complete absence of listener complaints concerning the relative loudness of speech and music. A few complaints continue to be received of course, but when specific cases are investigated it is almost always found that either (a) the recommended transmission practices were violated because of some special circumstance or (b) that the program originated on another network.

AUDIO PATENTS

[*from page 4*]

housing and is insulated acoustically (and positioned) by a foam rubber ring. Sound travels through a hole in the shelf.

Transconductance Tester

The same principle of checking gain by oscillation threshold is used by La Verne R. Philpott in his Patent No. 2,555,368 to find the transconductance of vacuum tubes. The patent contains the formulas by which actually calibration of the dial in micromhos is made possible, but the unit is also a simple and effective service tester for amplifier tubes.

As *Fig.* 4 indicates, the basis of the invention is an ordinary transformer-coupled audio oscillator with feedback adjustable through the setting of the arm on R_1, the plate load resistor of the tube. The amount of feedback necessary for the circuit to reach oscillation is determined by the G_m of the tube. To use the invention, a tester can be made up with the usual variety of tube sockets and switches for connecting the various leads to the right elements. Tubes known to be good are then inserted and biased as desired with the aid of R_2, part of a divider across the power supply. The calibrated dial is adjusted so that the circuit just breaks into oscillation, as indicated by

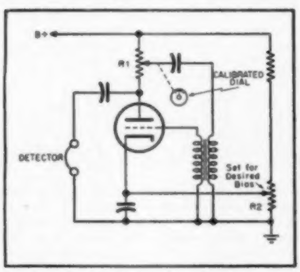


Fig. 4.

headphones, an electron-ray tube, or some other detector, and the dial reading is noted. Thereafter tubes of the same type which require the arm of R_1 to be set nearer to the plate end have less gain, how much less being indicated by the dial setting. Pentodes can, of course, be tested as well if voltage is provided for the screen.

Readers interested in investigating any of these patents further may obtain copies for 25 cents each from the Commissioner of Patents, Washington 25, D. C.

Employment Register

POSITIONS OPEN and AVAILABLE PERSONNEL may be listed here at no charge to industry or to members of the Society. For insertion in this column, brief announcements should be in the hands of the Secretary, Audio Engineering Society, Box F, Oceanside, N. Y., before the fifth of the month preceding the date of issue.

★ Positions Open • Positions Wanted

★ **Wanted:** Network caliber audio technician as chief engineer of large recording installation, New York area. Draft exempt preferred. State salary. Box 1001, **Audio Engineering.**

★ **Audio Engineers:** One amplifier and circuit designer. One audio with good mechanical background. Exceptional long-range opportunity in recording and business machine field. Permanent non-defense work in Connecticut. Send resumes to P. O. Box 29, Hartford 1, Conn.

★ **Mechanical Design Analyst:** For work in a small research group. Drafting and letter-writing background required with at least two years' experience designing small electro-mechanical mechanisms. A knowledge of audio and recording patents preferred. Permanent non-defense work in Connecticut. Send resumes to P. O. Box 29, Hartford 1, Conn.

★ **Sales Engineer** wanted by leading distributor of professional tape and disc recorders, playbacks, and all accessories. Man selected will be paid for knowing his stuff. Box 1002, **Audio Engineering.**

★ **Engineer:** experienced in vacuum tube circuit design and construction. Knowledge of audio frequency instruments and a.c. measurement techniques also required to fill position in test and development laboratory. Box 1003, **Audio Engineering.**

★ **Engineer:** to engage in development and construction of audio frequency circuits. Must be able to conduct investigations independently and to write up results in good technical style. Box 1004, **Audio Engineering.**

• **Recording Engineer,** American, with impressive English film background; familiar with all phases of film production from studio floor to laboratory, both aural and visual; desires connection in films or live television, USA or abroad. For details write or wire: John F. Higgins, 57 Juniper Road, Port Washington, New York.

NEW LITERATURE

• **Society of Motion Picture and Television Engineers,** 40 W. 40th St., New York 18, N. Y. announces the publication of "High Speed Photography", Volume 3. The 160-page book is an anthology containing reprints of articles of special interest to the general field of photography in engineering and research, which first appeared in the SMPTE Journal from January 1950 through January 1951. Copy may be obtained from Society headquarters upon remittance of two dollars.

• **Milo Radio and Electronics Corp.,** 200 Greenwich St., New York 7, N. Y. has assembled a remarkably complete listing of industrial and special-purpose electronic tubes in a new 28-page catalog which is being mailed on request. All major manufacturers are represented in the booklet, and technical specifications and prices are shown for all items listed.

• **Westinghouse Electric Corp.,** Box 2099, Pittsburgh 30, Pa., is publishing a 30-page booklet on the selection of electrical measuring instruments. Complete lines of portable, switchboard, panel, recording, and socket instruments are described and illustrated, and functions of each are explained. Requests for copy should specify Booklet B-4696.

• **Society of Women Engineers,** 103 Park Ave., New York, N. Y., has begun publication of a new official organ known as the "Journal of the Society of Women Engineers." The 16-page quarterly booklet will report on the activities of Society members and carry articles of general engineering interest.

• **Allied Radio Corp.,** 833 W. Jackson Blvd., Chicago 7, Ill., has surpassed even its own fine efforts of previous years with its new 1952 catalog of electronic equipment. Containing 212 pages with hundreds of illustrations, the catalog well exemplifies its title, "Everything in Radio, Television, and Industrial Electronics." This book should be considered a must by everyone, consumers and industrial users alike, involved in the buying of electronic parts and supplies. Will be mailed on request.

• **The Astatic Corporation,** Conneaut, Ohio, is now distributing a new general catalog which covers all products made by the company for civilian markets. Handily indexed on the front cover, the booklet is printed in three colors and contains illustrations of all items listed. Helpful for readers in the audio field is the practice of showing beside each phonograph cartridge a picture of the stylus it contains. Requests should be addressed to the Sales Department and should specify Catalog No. 51.

• **The International Nickel Company,** Development and Research Division, 67 Wall Street, New York 5, N. Y., is now issuing a new technical booklet on the resistance welding of nickel and high-nickel alloys. For anyone interested in this subject, the Inco booklet will be of great value. It contains 32 pages of worthwhile technical information, and is illustrated throughout by drawings and photographs. Will be mailed without charge. Address Technical Service Section and ask for Bulletin T-33.

• **International Resistance Co.,** 401 N. Broad St., Philadelphia 8, Pa., continues to maintain its high standard of technical publishing with Bulletin B-1, a 12-page booklet containing comprehensive data on characteristics and specifications of Advanced Type BT fixed composition resistors. There is no technical information a buyer could desire which is not included in this catalog which is to be commended for its excellence.

• **Rigidized Metals Corporation,** 662-P Ohio St., Buffalo 3, N. Y. has available an interesting 8-page booklet on the subject of metal conservation. Will be helpful to designers. Must be requested on company letterhead. Address Dept. A.

• **Insulation Manufacturers Corporation,** 565 W. Washington Blvd., Chicago 6, Ill. has compiled complete descriptive information and technical data on Dieflex tubings and sleevings in a new 8-page bulletin which will be mailed free on request. Will be of substantial interest to engineers and designers concerned with insulation of leads and wires in all types of electrical and electronic equipment. Address Publications Department and ask for Bulletin No. 250A.

MISMATCHING

[from page 16]

Substituting appropriate values for r_p and R_l the following results are obtained. The 6L6 and the 2A3 are used as representative tubes of a type.

For the 6L6, the connection of a load impedance 100 per cent higher than rated load causes an 83 per cent increase in gain. For the 2A3 the gain increase is only 14 per cent.

The connection of a load of 50 per cent of the rated value gives a 48 per cent decrease in gain for the 6L6 and a 20 per cent decrease for the 2A3.

The reason for the tremendous difference in behavior is, of course, that the plate resistance is much larger than the load in the case of the 6L6 and, consequently, the gain is determined by the load. The load is larger than the plate resistance in the case of the 2A3, and, therefore, the load has less control over the gain.

Effect upon Feedback

Many modern amplifiers, especially those of high quality, employ negative feedback to improve the performance, and manipulation of the load brings up problems which do not exist in ordinary amplifiers.

Negative feedback reduces the gain of the amplifier by the factor

$$F = 1 - A\beta_o$$

where β is the fraction of the output voltage fed back and A_o is the total gain of the amplifier. This factor is also the factor by which the distortion, hum, and noise of the amplifier are reduced by negative feedback. As the load (and therefore, the gain) of the final stage varies, the over-all gain A_o will vary in proportion, and, consequently, the gain reduction factor F will also vary. The amount of variation will depend on whether the output tubes are beam power or triodes and how large β is.

From the above it may be seen that changing the load value will also change the distortion, the hum, and the noise. Making the load impedance lower than its rated value will reduce the feedback, and, therefore, increase the distortion, hum, and noise for the same output. Making it higher will increase the feedback, and, consequently, reduce these non-signal components.

For example, two amplifiers have exactly the same gain A_o and the same β, but one has 6L6 output tubes and the other has 2A3's. The gain reduction factor with the correct load is 10, corresponding to 20 db of feedback. An increase in load impedance of 100 per cent will cause an increase in F of 73 per cent for the 6L6 amplifier, and of 12 per cent for the 2A3 amplifier. The distortion of the 6L6 unit will be reduced by 57 per cent and that of the 2A3 unit by 8.5 per cent. It must be remembered, however, that the initial distortion of the 6L6's has been increased, and that of the 2A3's reduced, due to the increase

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PROFESSIONAL DIRECTORY

in load and, consequently, the above figures do not tell the whole story.

It has been shown that change in the load impedance will produce changes in both frequency response and mid-frequency gain. In a negative feedback amplifier the gain vs. frequency response characteristic must be closely controlled in order to ensure that the feedback be negative at all points where the gain is unity or greater. The designer generally chooses a margin of stability in order to allow for gain changes due to all causes. A common minimum value for this margin is 6 db, which means allowing for a total variation of 2 to 1. A 100 per cent change in load may change the frequency response at either end by almost this much, thus practically eliminating the margin of stability. In better-designed amplifiers this margin is considerably more, and mismatching may be done much more safely from the stability point of view.

In general, within the limitations of power output discussed in the cited reference, mismatching may be quite readily accomplished. If deterioration of performance is to be avoided, the above factors should all be taken into consideration before any changes are made.

Industry People...

Dr. Albert Charles Walker of Bell Telephone Laboratories has been awarded Louis Edward Levy Medal by The Franklin Institute . . . **Leonard Carduner** of British Industries Corp. in England for a look-see at new audio developments—expects to return in time for The Audio Fair . . . **James M. Valentine,** former TV engineering head of ABC's Central Division, named an executive in TV field engineering group by Federal Telecommunication Laboratories—will headquarter in Buenos Aires.

Heckert Parker justly commended by re-appointment as manager of Annual Pacific Electronic Exhibit . . . Appointment of **Howard W. Bredlow** as Chicago district manager is newest step in expansion of Hoffman Radio Corp. into Eastern markets . . . **Bernard Hecht** moves from RCA-Victor to Starrett Television Corp. as General Manager . . . **Miss Beatrice Hicks** re-elected president of Society of Women Engineers—other officers are Miss Lillian Murad, vice-president; Mrs. Hilda Edgecomb, treasurer; Mrs. Barbara Cain, recording secretary, and Mrs. Phyllis Evans Miller, corresponding secretary.

Eugene F. Haines retiring as assistant treasuer of RCA Victor Division of RCA after serving 50 years with Division and predecessor companies . . . **Lester Klein** tops years of activity in radio merchandising business with new position as manager of downtown branch of New York's Hudson Radio & Television Corp. . . . **Ralph Schlegel** busy installing new equipment for WOR Recording . . . **Coleman London** upped to manager of electronics service for Electronics and X-Ray Division of Westinghouse . . . **George C. Mercer** and **W. J. Topmiller** become Director of Purchasing and Purchasing Agent respectively as result of promotions by P. R. Mallory & Co., Inc., Indianapolis.

Miryam Simpson, vice-president of Mark Simpson Mfg. Co., announces formation of Masco Electronic Sales Corp. to handle distribution of all Masco products . . . **George E. Faustman** has been named factory general manager of the Bendix Radio Division of Bendix Aviation Corp. to succeed Edward F. Kolar who becomes general manager of company's Red Bank Division . . . **Fred Harvey,** Sylvania ad manager, back on the job after a session in uniform . . . **Charles Ray,** Sound Department manager for Arrow Electronics, New York, busy building unique display centered around a "Then and Now" theme for The Audio Fair . . . **Bob Hertzberg,** pioneer technical writer and editor, has set up shop as consultant to manufacturers and advertising agencies.

ADVERTISING INDEX